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CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

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CONTENTS

CONTENTS (continued)

IMPORTANT TASKS OF STATE INSPECTION LABORATORIES FOR MEASURING EQUIPMENT

B. L. Sokolov

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 1-3, December, 1961

The Russian people met with enthusiasm and were inspired by the decisions of the 22nd CPSU (Communist Party of the Soviet Union) Congress, which adopted the new program of our party, the program for building communist society.

The main economic task of the new CPSU program consists in establishing during the next two decades the material and technical foundations of communism. "This means complete electrification of the country and perfection on this basis of the techniques, technologies, and organization of social production in all the fields of the national economy; comprehensive mechanization of production operations and a growing degree of their automation; widespread use of chemistry in the national economy; vigorous development of new, economically effective branches of production, new types of power and new materials; all-round and rational utilization of natural, material and labor resources; organic fusion of science and production, and rapid scientific and technical progress; a high cultural and technical level for the working people; and substantial superiority over the more developed capitalist countries in productivity of labor, which constitutes the most important prerequisite for the victory of the communist system."

The rapid development of our national economy will require modern measuring equipment and highly efficient systems of production automatic control. New measuring methods and instruments will appear, based on the latest achievements of science and technology, on the use of radioactive radiations, ultrasonic methods, infrared radiations. The application of atomic energy in our national economy, in medicine and science will produce a further development and improvement in the most up-to-date measurement equipment.

These outstanding developments require new methods for organizing and carrying out the work of state inspection laboratories (GKL) for measuring equipment. The GKLs must study the economy of their district and base their work on the specific needs and requirements in the sphere of metrology and measurement equipment.

The GKLs must be fully prepared for solving problems which face them in connection with the tasks of our national economy in creating the material and technical foundations for communism.

The development of Soviet economy cannot be contemplated without a systematic improvement in the quality of production. Soviet establishments in this respect must also outstrip the best capitalist plants. In view of these requirements the role of the GKLs is greatly enhanced, since they must supervise the adherence to and assimilation of new, more advanced standards and ensure the rectification of any of their infringements.

It is recommended to involve in this activity on a wide scale the representatives of social organizations, which should in the near future produce a considerable improvement in the quality of production.

The GKLs must also assist in organizing in their district standardization and normalization, and the provision in the plants of appropriate organizational changes if required.

We must support the valuable patriotic initiative of the leading Moscow plants, which are striving to raise the serviceability and quality of industrial products. We must organize in each region, territory and republic competitions for the achievement of these characteristics, and involve in this competition the Sovnarkhozes (Councils of national economy) and the regional committees of trade unions.

The GKLs have responsible and varied tasks in instrument-making. They must understand perfectly well the organizational and technical problems in this sphere, establish a clear-cut and strict supervision of the quality of manufactured intruments and of state testing of instruments whose production is being organized by industry; they must systematically inspect the condition of reference measures and instruments as well as of the measuring equipment in each instrument-making plant.

Special attention should be paid to discontinuing the production of obsolete measuring instruments. The activity of the GKLs in this respect should be made considerably more effective. They should insist that the appropriate organizations should forbid the production of such instruments.

They should not limit their evaluation of any instrument to state testing results alone, it is also necessary to take into account its operational properties and characteristics. The latter information should be systematically collected by the GKLs.

The republican administrations of the committee should assist in collecting this information.

Considerable importance should be attached to the participation of the GKLs in scientific and technical societies, through which they can conduct propaganda of metrological principles and take practical steps for improving the measurement equipment in our national economy.

Technical councils attached to the GKLs must be established wherever possible, since in their capacity of consultative agencies they should deal with the most theoretically important technical, economic and production problems in the sphere of measurement technology, state and service inspection of gauges and instruments, in instrument-making and the repair of instruments, in observing and assimilating standards, etc.

Technical councils will raise considerably the role of the GKLs as organizational and technical centers for measurement technology, and will assist in the speedy assimilation of the latest measurement equipment.

In order to carry out the new and complicated tasks, and to satisfy the requirements of our national economy in the sphere of measurements and testing, the GKLs must themselves be equipped with high quality reference measuring equipment, and their obsolete equipment must be replaced. For high precision metrological work it is necessary to equip Grade 1 laboratories with special air-conditioning installations.

It is necessary to reorganize the Committee's area inspection agencies on the basis of the measurements they carry out (ionizing radiations, gas analysis, acoustics and hydro-acoustics, lighting engineering) and establish in a number of Grade 1 GKLs (State inspection laboratories) area repair and adjustment workshops with travelling crews for the installation, adjustment and repairs of reference instruments in the GKLs. This type of work should also be extended to the Committee's institutes.

The vigorous development of industry, especially in the areas east of the Urals, the construction of superpowerful hydro-electric power stations of the Angara-Enisei chain and of large thermal-electric power stations make it necessary to plan in the development of the GKLs their timely supply with the required latest test equipment. It is also necessary to extend and accelerate the construction of buildings for the GKLs in the eastern regions of the country and the Union republics of Central Asia.

The further development of our agriculture, envisaged by the CPSU (Communist Party of the Soviet Union) program, and the wide and rapid electrification of agriculture will raise the importance of measurements in that sphere and will considerable increase the stock of measuring instruments. This stock will not only increase in size, but its composition will also change in favor of more complex instruments.

State supervision of measuring equipment in rural districts requires the rapid and widespread organization of travelling test laboratories covering various types of testing, and providing on-the-spot testing and inspection of measuring intruments used in agriculture and in plants far removed from towns.

It is most important to develop in the near future portable test equipment suitable for field use and supply it to the GKLs, thus facilitating the testing of measuring equipment in the plants and organizations. It is also necessary to revise the Committee's specifications such as directives and operating instructions on testing gauges and measuring instruments by deleting from them superfluous requirements and simplifying the testing technique, especially for instruments at present in use.

It is necessary to improve the planning and rate-fixing for the work done in the GKLs, skilfully to combine annual and long-term plans, to develop effective basic accountancy and a system of graded indices for the purpose of developing the creative initiative of the GKL workers. Improved planning will help to raise the role and the interest displayed by the GKLs in introducing new equipment in our national economy, in rendering maximum assistance to the instrument-making industry, in popularizing new methods and principles of measurement, in developing the service inspection agencies for gauges and measuring instruments, etc.

The new technology and the reduction of working hours call for higher efficiency in labor organization. It is necessary to plan a more rational distribution of work in various laboratory departments.

It is necessary continuously to improve the qualifications of state inspectors, to make them capable of replacing one another in various testing operations, to raise them from the level of routine workers to that of masters of their craft, to instil in them greater independence of judgment and initiative, a new, communist attitude to work.

The new CPSU program notes that technical progress will require a considerable improvement in the efficiency of production, and in specialized and general training of all the workers. State inspectors must possess the knowledge and habits of an engineer in order to be able to understand the latest measuring-instrument and equipment circuits, to master the use of the latest measurement equipment and to test it efficiently. It is, therefore, necessary to encourage the GKL workers who do not possess a higher education to study in correspondence and evening classes of higher technical educational institutions.

It seems advisable to organize in the Committee's network a permanently functioning educational system for training and raising the metrological qualifications of the GKL workers, since the majority of laboratories lack such facilities.

It is necessary to regularize the method of preparing and taking examinations for the degree of a certified state inspector in the Committee's institutes. It is necessary to involve in this work Grade 1 state inspection laboratories for measuring equipment whose technical possibilities and the qualifications of whose personnel will provide efficient training for the workers in the nearby GKLs. In training this personnel special attention should be paid to making state inspectors fully prepared to work under conditions when our national economy is developing in the direction of complete automation and mechanization and the adoption of completely new technological processes.

Periodic seminars should be held on problems of measurement techniques; the heads of the GKLs which have acquired many new workers should attend refresher courses in order to raise their metrological qualifications and study the latest achievements in the sphere of measurement technology, standardization and normalization.

The outstanding task consists in the widespread application of the experience of the best GKLs in order to raise labor productivity, improve the quality and organization of work. The experience acquired by the GKLs should be exchanged in a planned, convenient and profitable manner. For instance, group seminars for leading GKL workers with a description and discussion of the work of the leading laboratories have proved to be successful. It is also necessary to study with the help of the international organization of legal metrology the experience gained in inspection work by leading foreign metrological organizations and to apply anything that is found useful in this experience to the work of the GKLs in the Soviet Union.

The heads of laboratories should center their attention on rationalization proposals and inventions. It is necessary to support with all available means the work of the best GKL workers who display creative ability and initiative and overcome obsolete traditions, and to apply their achievements in the work of the laboratories. The material and moral encouragement of rationalizers and inventors is of prime importance.

An important role in the solution of these tasks should be played by labor competition and a communist attitude to work. Competition between the GKLs should be widely developed for higher labor productivity, assimilation of new measuring equipment in routine testing, mastering of new testing methods, effective implementation of organizational measures which improve the measuring equipment in our national economy, etc. New competition methods should be found. One can point as an example in this respect to the initiative shown by the personnel of the indicating and recording electrical measurement instruments laboratory of the VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments) and the state-and-check-testing group of the Krasnodar GKL, who are competing for the coveted title of a communist labor personnel and at the same time are rendering each other assistance in solving practical problems.

GKL production conferences should become essentially important, the role of the GKLs should be raised in planning the activity of the laboratories, and all specific questions should be subject to thorough and exhaustive discussion.

In checking the work of the GKLs the main attention should be paid to the implementation of the party and government decisions and the tasks set them by the Committee, to their practical activity and actual fulfilment of the plans.

The experience gained by the RSFSR (Russian Socialist Federated Soviet Republic) deserves to be emulated in checking the activity of any GKL by the heads of two or three other GKLs, with the subsequent discussion at a group conference of the results of such an inspection and of practical steps taken to eliminate shortcomings.

The development and improvement of the GKLs' activities will require considerable assistance from the Committee's institutes and republican administrations. It is advisable to organize fruitful cooperation between the workers of the Committee's institutes and the GKLs.

It is necessary to insist that the Committee's republican administrations should solve simply and rapidly the problems confronting them, and should supervise the work of the state inspection laboratories without bureaucratic tendencies or procrastination. The administrations should have qualified personnel capable of rendering practical assistance on the spot.

A full understanding of the outstanding social obligations and responsibilities conferred on state inspectors of measuring equipment by the USSR government, conscientiousness, honesty and cooperation, these are the moral principles by which the GKL workers should be guided in their activity in order to be equal to the tasks set them by the Communist Party and the Soviet people.

DEFINING THE CONCEPT OF MEASUREMENT*

K. B. Karandeev, V. I. Rabinovich, and M. P. Tsapenko

Translated from Izmeritel'naya Tekhnika, No. 12,
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The theory of systems for selecting, processing, storing and supplying information in a digital form, that of measuring information systems [1], is now being established. It seems natural to use the theory of information methods for analyzing and synthesizing automatic systems of this type. However, it is hardly possible to transfer mechanically from the theory of information to that of measurements the concepts and terms which have received a specific significance in the first-named theory. On the other hand, some of the existing metrological concepts require verification in view of the development of a new trend in the theory of measurements. In the first instance this applies to the concept of measurement, whose definition was formulated at a time when the basic means of measurement consisted of pointer and manually operated instruments.

In this article we provide an anlysis of the existing definition of measurement, and suggest and justify a new interpretation of this concept.

• • •

I. It is generally accepted to call measurement the cognition process which consists of comparing by means of a physical experiment the measured physical quantity with a certain value of that quantity adopted as a unit of comparison (measurement) [2, 3, etc.]. This definition has not lost its significance and, for instance, still holds for direct, nonautomatic measurements. However, in our opinion, the theory and practice of measurements definitely require clarification and partial amendment of the above definition. Let us quote a few considerations which confirm the above opinion.

1) The rapidly increasing requirements for the automation of production and experimental investigations (in the wider meaning of the word) entail a rapid development of automatic measurements. In automatic measurements the operator is, to a certain extent, relieved from participation in the measurements. In many instances the measurement results are used for direct automatic control of certain processes. In such cases it is hardly possible to consider measurements as a cognition process, since the latter presupposes the presence and actions of a human operator.

2) In measuring instruments the readings have two basic forms.

*Contribution to a discussion.

a) a continuous form, characterized by the fact that the number of possible reading points is infinite. Such a form of indications is characteristic of pointer instruments, analog recorders, etc.;

b) a discrete form of reading, which is characterized by a finite number of points. This group includes digital measuring instruments which are based on quantization and digital coding [4]. (By quantization we understand an approximation of a continuous quantity to the nearest scale division, and by digital coding the expression of the quantized measured quantity in a digital form.)

In measurements made by means of instruments of the analog type the quantization and digital coding are done by the human experimenter.

Thus, the measuring operations differ in instruments with different types of reading. Therefore it is difficult to answer the question when any given measurement should be considered complete. The definition of measurement which is at present adopted makes it impossible to eliminate the existing ambiguity.

It is clear that measurement is a specially prepared process whose results can be used without any additional operations. A measurement result which can be used directly consists of a numerical expression of the measured value. Such a posing of the problem in each specific case provides a single-valued answer to the question whether the process has been completed or not. Moreover, it becomes possible to define precisely the instruments in which the measuring process is completely automatic. This group includes only automatic digital measuring instruments in which all the required operations are made without the participation of a human operator.

In defining the term measurement it is advisable according to the above reasoning to note that the measurement result must be presented in a digital form.

3) A clearly distinguishable tendency in modern measurement techniques consists of raising the relative importance of indirect and combined measurements. In such methods the unknown variable has a functional relationship to the variables whose values can be obtained by direct measurements. The final result is obtained by determining the functional relationship, thus involving appropriate logical and computing operations. In automatically operating measuring instruments these operations, which are required for obtaining the result in a final form, are completed without the participation of a human operator. When nonautomatic instruments are used the logical and computing operations must be performed by the experimenter himself. Let us note that in certain measuring instruments (for instance, electrodynamic and moving-coil wattmeters) the devices which perform the comparison and computations have, for a long time, been constructed in a combined common unit.

In view of the above reasoning it should be pointed out that measurements must include the required logical and computation operations.

4) We also consider it completely incorrect to use the adjective "physical" for indicating the material nature of the experiment and the compared quantities. It seems to us that comparison may include, physical, chemical and other quantities. The same reasoning may be applied to the types of experiments performed. It is, therefore, inadvisable to indicate in the definition of measurement the nature either of the measured quantity or the experiment.

In view of the above reasons we suggest the following definition: "Measurement is a process of obtaining information which consists in comparing experimentally known and unknown quantities or signals, in performing the required logical and computing operations and presenting the information in a digital form."

Let us make additional explanations of some of the peculiarities of this definition.

The term comparison is used in the above definition in the sense of the juxtaposition of similar quantities, namely, measured and known quantities. The values of these quantities can be compared by performing the required number of subtracting or dividing operations. The comparison method or technique can vary considerably. It is also asserted that the comparison must be made by a purely experimental method which may include either the measured quantities or the signals corresponding to them and obtained by means of intermediate transformations.

Let us also note that the comparison need not be simultaneous [3]. In such a case a certain reference quantity (measure) is used either for calibrating an auxiliary quantity which is employed in direct measurements,or for replacing (substituting) the measured quantity. The substitution method of measurements consists of comparing the effects produced by the compared quantities or the signals corresponding to them.

It should also be noted that the term "comparison" is not basic and its interpretation may not be single-valued. In this connection we may require in future a more detailed analysis of this concept.

Finally, it is suggested that the measurement be considered as completed if the measured information is presented in a digital form.

It appears to us that the above formulation is suitable for characterizing direct, indirect and combined, automatic and nonautomatic measurements, and makes it possible to determine whether the measurement process has been completed. This definition also shows that it is impossible not to take into consideration the information characteristics of the measured systems.

* * *

II. The suggested definition of the concept of measurement includes the terms information and signal, which have such a wide content that they can be considered as philosophical terms. There is, however, no accepted definition of the above terms.

A probability approach [5–10 and others] seems the most justified in dealing with the concept of information. Such an approach provides a sufficiently wide interpretation of this concept for characterizing a most varied range of phenomena and conditions, and for introducing a measure of the quantity of information. However, the authors of the above works do not consider a quantitative measure of the value of information to be essential. It is difficult to agree with this opinion, since an analysis of information received from the phenomena under investigation is of paramount interest. The introduction of a measure of the value of information will provide new possibilities for investigating the measurement results and designing measuring systems to be optimum in the widest meaning of the word. The publication of works [11, 12] provides the hope that the required criteria will be found.

The probability nature of information makes it impossible to formulate its definition without using the terms accepted in the theory of probability and in mathematical statistics. Experiment is one of these terms. Experiment is defined as the implementation of certain conditions and actions. Such an interpretation provides the possibility of examining any happenings of practical interest. Event is another necessary term. In the theory of probability event is the qualitative result of an experiment. In defining the concept of information we must, in addition to the above considerations, also reflect the following two circumstances.

1) "Information" is undoubtedly a collective term for denoting the contents of the studied processes and phenomena independently of their nature. Moreover, it is assumed that the content of the phenomena and processes may be of a most diverse nature. If there is no diversity, no multiplicity of possibilities, the use of the term information cannot be justified. Hence, the possibility of selection is prerequisite for obtaining information. The information contains the qualitative results of this selection, i.e. implemented events. Hence, in defining the term "information" we must deal with the content of events.

2) It is essentially important to know what constitutes the difference in an experiment before and after the contents of an implemented event become known. The answer is obvious, the initial indeterminacy of the experiment changes. This reflects the essence of information. In our opinion it would be incorrect to consider only a reduction in the indeterminacy. Such an approach would impede the establishment of a measure of the value of information, since a content of events is possible which will lead to a rise of indeterminacy in an experiment.

On the basis of the above considerations it is possible to make the following definition: "Information denotes a content of events which have an initial experimental indeterminacy."

This definition is in complete agreement with the formulas adopted for calculating the quantity of information. At the same time it does not contradict the fact that the value of the same amount of information may differ.

Let us now describe the considerations which were adopted in formulating the definition of the concept signal.

There is no doubt that a necessary condition for selecting information from a process under consideration and the storing and transmission of this information is provided by a property of matter which approaches perception, namely, a property of elementary mapping. The phenomena which occur in the mapping process or arise as a result of it contain information on the causes which have produced this process. These phenomena provide the information, since they make it perceptible. These phenomena are denoted by their information content as signals.

Let us now note the most important characteristics of the phenomena which occur in mapping processes, namely, of signals. Under appropriate conditions these phenomena can remain invariable for an indefinite time. It is precisely these properties of signals which are used in "memory" devices. Another equally important property of signals consists of their ability to react on certain objects of the material world. These reactions produce new phenomena which

are also signals, etc. Without such a chain of reactions it is impossible to consider the propagation of signals, and, hence, the transmission of information.

The above considerations have made it possible to formulate the following definition: "A signal is a phenomenon which serves to transmit information by means of reactions."

* * *

In conclusion let us note that measuring devices are a variety or a part of information systems. The extension of the sphere of application and the raising of performance requirements of automatic measuring information systems require a search for new methods of their analysis and synthesis. The application of such information theory characteristics as entropy, carrying capacity, redundancy, etc. is very convenient in studying the potentialities of measuring information systems by comparing them to each other and determining their approximation to an optimum design. In order to develop rapidly the theory of measuring information systems it is necessary to use and appropriately evolve the techniques of the information theory, the theory of algorithms, and linear and dynamic programming.

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DETERMINING IN STATE TESTING WHETHER INSTRUMENTS ARE RELIABLE AND SUITABLE FOR MASS PRODUCTION

M. A. Zemel'man and N. I. Tyurin

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 7-8, December, 1961

In state testing of experimental models of measuring instruments a number of important questions need to be solved, for instance, whether the instrument meets the requirements of our national economy; whether its principle of operation, circuit and construction are up-to-date; and whether it ensures uniformity of measurements under various specified conditions of operations. The reliability of instruments and the possibility of their mass production are also important questions.

Under capacity for mass production we understand the properties of the instruments' circuits and construction which ensure the required quality of instruments when they are assembled from components which are made according to definite technical specifications and drawings and meet the tolerances specified for them. No theory has as yet

been developed for determining reliability and there are no clear criteria for evaluating it. Nevertheless, it is necessary in testing to seek means for deciding whether an instrument of a given construction under consideration will be serviceable for a relatively long time.

The technique of determining the basic properties of a circuit and lay-out of an instrument which would provide the possibility of mass-producing it and a reliable operation is far from clear, and its development encounters great difficulties. These difficulties are increased by the fact that only very few models of inspected instruments are subjected to state testing, sometimes only one model. However, it is already possible to outline an approach to testing which would provide some, although incomplete, idea of the above properties of the instruments.

The specified technical characteristics of an instrument must be provided in future in each mass-produced model. For this purpose it is necessary that the circuit and lay-out of the instrument should satisfy at least two conditions:

1) all the components and units of the instrument constituting semi-finished articles, which are used in the instrument in a ready-made condition, and are manufactured according to specification, must operate in the instrument under conditions provided by the specifications of these components and units;

2) the instrument must possess specified technical characteristics even when the components and units possess the worst possible parameters within the specified tolerances.

The non-observance of the first condition leads to a reduction in the life of the instrument and cannot be tolerated.

The resolving of the second condition is more complicated. In fact, if the instrument consists of a large number of mass-produced components the requirement of providing normal operation of the instrument in the case of the worst possible tolerated parameters of the components may be considered from the point of the view of the theory of probability to be rather exaggerated.

However, in many practical instances we can approach the second condition in a much simpler manner. If the instrument contains a large number of components, there are always some whose parameters play a decisive part, whereas the parameters of the remaining components have a less important effect. When models of such instruments are subjected to state testing it is advisable not to be content with determining their technical characteristics in the state in which they are submitted for testing, but also to determine their technical characteristics if certain components are replaced by similar components possessing the worst possible parameters tolerated by their specifications. If the technical characteristics of the instrument then fall below the specified requirements, it means that the instrument cannot be manufactured under normal mass production conditions. It is also possible to examine the question of whether a special selection of components is permissible in the manufacture of the given instrument. However, even when the components are selected it is still possible to consider that the instrument is not highly reliable, since the parameters of the components may not be constant, and can change with time within the limits specified for the components.

The use of the above technique in state testing has shown that the designers of the instrument in many cases do not take into consideration the above conditions for ensuring that the instrument can be mass-produced and is reliable. For instance, in some automatic electronic potentiometers and bridges one-half of a double triode is used as a kenotron in an amplifier circuit, and the other half serves as one of the amplifier stages. The voltage between one of the cathodes and the heater exceeds the value specified for the tube. Moreover, the reverse voltage between the grid (which is connected to the anode) and the cathode, in a nonconducting kenotron attains values which are hardly permissible for this tube. All this must lead to a reduction in the instrument's reliability and in the life of the tube. In the same and certain other instruments the winding of the reversible motor is connected in series with a capacitor, the ac voltage across whose terminals exceeds the maximum value specified for this type of capacitor. Other similar instances could be cited.

The instrument designers do not always take into account the lowest tolerated parameters of components used in the instruments. For instance, state testing of certain automatic electronic potentiometers used in pH-meters has revealed that for the maximum specified leakage across capacitors at the input of the amplifier and across the socket pins of the amplifier first-stage tube, the readings of the instrument change beyond permissible limits, and the effect of the transducer resistance variation has too great an effect on the readings of the instrument. In order to eliminate this defect, which was discovered in state testing of the ÉPPV-5280 sets, certain circuit and constructional alterations

have been made which have improved the mass-production possibilities and other important characteristics of the instrument.

The mass production of ÉPP-22 was considered inadvisable owing to similar defects having been discovered during state testing.

In considering the technique of discovering the reliability of instrument circuits and constructions it is necessary to examine yet another important question. Many present-day instruments include negative feedback systems. It is known that negative feedback reduces considerably the effect of various undesirable factors on the characteristics of the instrument. Hence, in testing instruments with a closed feedback circuit it is difficult to determine the effect of component parameter variations, since they are masked by the feedback. It is also difficult to determine whether the technical characteristics of the instrument under test are random and peculiar to the given instrument, or whether they reflect properties of the circuit and the construction of the instrument. In order to arrive at a correct estimation of the circuit and construction of the instrument it is necessary to determine its properties with a disconnected feedback, including such characteristics as the open circuit transfer constant and the characteristics of the instrument components which could produce variations in the readings or in the normal operation of the instrument. It then becomes possible to calculate the variations in the instrument readings due to the possible (tolerated) variations in the component parameters and to external factors with the feedback circuit connected.

A characteristic example of such instruments includes those using photocompensated amplifiers. These instruments comprise sensitive galvanometers, photovaristors or photocells, and sometimes electron tubes. The above components consist of finished articles, are essentially unstable and some may have parameters which differ from the rest within certain limits. It is only the use of a negative feedback that provides the possibility of employing these components in relatively accurate instruments.

Even if the tolerated dispersions of the instrument component parameters and their instability are known, it is still difficult to determine the general technical characteristics which the instruments will possess for different (within permissible limits) parameters of their components. This means that the testing of instrument models does not in general reveal its fundamental characteristics. The testing of instruments with a disconnected feedback circuit makes it possible to determine the gain of the system and, hence, the basic characteristics of the instrument, and to evaluate the advisability of chosing a given circuit or construction. One of the basic operations in state testing of automatic electronic potentiometers and bridges should be their testing with a disconnected feedback.

The above considerations on the technique of state testing require further elucidation and not only with respect to electronic instruments.

Editorial Note. This article, which expresses the experience gained by its authors, is printed in order to raise the whole problem and attract attention to the great importance of providing the required quality in instruments. The Editorial Board requests readers to express their opinion on the above question.

A METHOD OF RAISING THE ACCURACY OF MEASURING SYSTEMS

N. A. Chekhonadskii

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Measurement systems are often used under complicated conditions characterized by considerable variations in the ambient temperature and in the supply voltage, by the presence of linear and vibrational accelerations, as well as other external factors whose variations with time are of a random nature.

Methods for raising the accuracy of measuring devices. Errors in a measuring instrument which is intended for measuring physical quantities varying with time and is continuously subjected to external effects depend, as it is known, on the nature of the measured quantity's variations with time and on the basic and additional errors of the device. Hence, the error of a measuring instrument can be conventionally represented as

$$\delta(t)=F\left[x(t),\ \delta_0(t),\ \sum_{l=1}^{m} Z_l(t)\right], \tag{1}$$

where $x(t)$ is the measured quantity; $\delta_0(t)$ is the basic error of the measuring device; $Z_l(t)$ is the random external disturbance affecting the measuring device; m is the number of external disturbances.

The above relationship, providing it can be expressed in a final form, determines the accuracy of a measuring device under actual operating conditions. Hence, the physical essence in designing measuring instruments of a given accuracy amounts to developing a device whose error function determined by (1) should at any instant t_1 satisfy the condition

$$\delta(t_1) \le \Delta, \tag{2}$$

where Δ is the error specified for the measuring device.

It will be seen from (1) that the error of the device is due to three basically different causes.

Leaving aside the effect of the nature of changes with time in the measured variable and of the measuring instrument's basic error on its total error, let us examine in greater detail the method of decreasing the portion of that error due to the effect of external disturbances on the measuring device. This problem is of considerable importance, since it is known that the static accuracy of measurements deteriorates considerably owing to various external disturbances. Whereas the methods of decreasing the dynamic error due to rapid variations of the input variable $x(t)$ have already received adequate treatment in literature.

It will be seen from (1) that for meeting requirement (2) there exist two basically different methods. One method consists in meeting requirement (2) only by providing the device with an appropriate functional relation of its error to the external disturbances. The second method consists in reducing the effect of these disturbances. A combination of the first and second methods is also possible.

In the first instance condition (2) is met by using in the construction of the measuring device special materials which are affected but little by external disturbances, and by means of various compensation circuits which reduce the effect of these disturbances on the error of the device.

In the second instance the measuring instrument's error is reduced by shielding it from the undesirable effect of external disturbances. This method is most widely used for measurements under laboratory conditions when special precautions are taken to maintain a constant ambient temperature, a constant supply voltage, etc. This method of reducing the error is partially used in the design of commercial measuring instruments.

These methods, however, cannot completely ensure the required accuracy in measuring instruments owing to a further rise in accuracy requirements under more complicated operating conditions (increased overloading, larger temperature range, etc.).

Control signal method. Let us now examine a linear measuring system consisting of n links and subjected to m external disturbances.

The structural schematic of such a system is shown in Fig. 1.

The output variable of a measuring system with slow variations both of the measured quantity and external disturbances can be expressed according to [1] as

$$y(t)=k_p\, x(t)+\sum_{i=1}^{n} k_i^{*}\left\{\Delta_{0i}(t)+\sum_{j=1}^{m} \beta_{ij} Z_{ij}(t)\right\}, \tag{3}$$

where $x(t)$ is the input variable of the measuring system; k_p is the resultant transfer constant of the measuring system; k_i^* is the transfer constant of a portion of the measuring system comprising the links from $i+1$ to n; $\Delta_{0i}(t)$ is the basic error of the i-th link of the measuring system; $Z_{ij}(t)$ is the j-th external disturbance which affects the i-th link; β_{ij} is the sensitivity of the i-th link of the measuring system to the j-th external disturbance.

Let us assume that $1 \le \mu \le n$ and that the μ-th link of the measuring system receives a control signal $B_{0\mu}(t)$ which is a function of time and can be repeatedly reproduced with a high degree of accuracy and that the section of the measuring system contained between links 1 to $\mu-1$ is disconnected at that instant.

Let us find the value of the output variable for the measuring system in this case. In view of the fact that the links of the measuring system under consideration have both basic and additional errors, the output variable of the measuring system can be represented when the μ-th link is fed with control signal $B_{0\mu}(t)$ by

$$B(t)=k_{\mu n} B_{0\mu}(t)+\sum_{i=\mu}^{n} k_i^{*}\Big\{\Delta_{0i}(t) + \sum_{j=1}^{m} \beta_{ij} Z_{ij}(t)\Big\}+\varepsilon(t), \tag{4}$$

where $k_{\mu n}$ is the transfer constant of the part of the measuring system between links μ and $\underline{n}$; $\varepsilon(t)$ is the error of the device which produces the control signal.

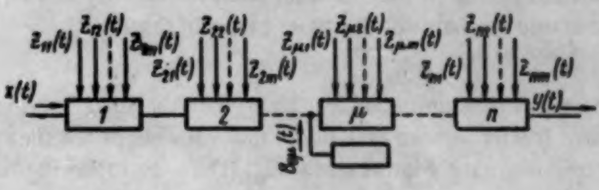

Fig. 1

In the last expression the second and third terms contain the basic and additional errors arising in that part of the measuring system which is involved in the conversion of the control signal when it is fed to the μ-th link.

The sum of the basic and additional errors of the system's links contained in the brackets of expression (4) we shall call total error. Thus

$$\Delta_c(t)=\sum_{i=\mu}^{n} k_i^{*}\Big\{\Delta_{0i}(t)+\sum_{j=1}^{m}\beta_{ij} Z_{ij}(t)\Big\} \tag{5}$$

represents the total error of the system's section between links μ and $\underline{n}$.

It will be seen from (4) that the value of this error can be represented as

$$\Delta_c(t)=B(t)-k_{\mu n} B_{0\mu}(t)-\varepsilon(t). \tag{6}$$

Thus, if control signal $B_{0\mu}(t)$ is fed to the μ-th link and the output variable of the system is measured, it is possible to find the total error of the system's section between μ and $\underline{n}$ providing its transfer constant is known. This fact can be used for a considerable increase in the accuracy of measurements made by means of the above system. For this purpose let us find the total error $\Delta_c(t)$ of the same section of the system when it is measuring an input variable x(t).

It can easily be seen from (3) that the output variable of the measuring system can be represented as

$$y(t)=k_p x(t)+\sum_{i=1}^{\mu-1} k_i^{*}\Big\{\Delta_{0i}(t)+\sum_{j=1}^{m}\beta_{ij} Z_{ij}(t)\Big\}+\sum_{j=\mu}^{n} k_i^{*}\Big\{\Delta_{0i}(t)+\sum_{j=1}^{m}\beta_{ij} Z_{ij}(t)\Big\}. \tag{7}$$

Let us subtract from the right- and left-hand sides of (7) the total error $\Delta_c(t)$ found experimentally and determined from (5) and (6):

$$y(t)-\bar{\Delta}_c(t)=k_p x(t)+\sum_{i=1}^{\mu-1} k_i^{*}\Big\{\Delta_{0i}(t)+\sum_{j=1}^{m}\beta_{ij} Z_{ij}(t)\Big\} + \sum_{j=\mu}^{n} k_i^{*}\Big[\Delta_{0i}(t)-\bar{\Delta}_{0i}(t) + \sum_{j=1}^{m}\Big\{\beta_{ij} Z_{ij}(t)-\beta_{ij}\bar{Z}_{ij}(t)\Big\}\Big]+\varepsilon(t). \tag{8}$$

where $\overline{\Delta}_{0i}(t)$, $\overline{Z}_{ij}(t)$ are respectively the basic error of the i-th link and the j-th external disturbance affecting the i-th link at the instant the control signal is transmitted.

It can easily be seen in analyzing the above expression that if the conditions

$$\begin{aligned} \Delta_{0i}(t) &= \overline{\Delta}_{0i}(t), \\ Z_{ij}(t) &= \overline{Z}_{ij}(t) \end{aligned} \tag{9}$$

are satisfied, the right-hand side of expression (8) will contain the total error of only that part of the measuring system which is not involved in transforming signal $B_{0\mu}(t)$, i.e. the total error of the links between 1 and $\mu-1$ and the error of the device which provides the control signal.

It is easily seen from analyzing (8) that the conditions (9) can be fulfilled if the control signal is fed for a short time so that the external conditions during its reception remain substantially constant. In the right-hand side of (8) there can remain some uneliminated remnants of the basic errors in the links between μ and $\underline{n}$ owing to the random nature of these errors.

In order to correct the system's measurements for the error in the links between μ and $\underline{n}$ let us use expressions (3), (6) and (8). From the above it will be seen that the output variable of the measuring system can be corrected for the error of the section which transforms the control signal $B_{0\mu}(t)$ in the following manner:

$$y(t)-\overline{\Delta}_c(t)=k_p\,x(t)+\sum_{i=1}^{n}k_i^*\left\{\Delta_{0i}(t)+\sum_{j=1}^{m}\beta_{ij}Z_{ij}(t)\right\}-B(t)+k_{\mu n}B_{0\mu}(t)+\varepsilon(t). \tag{10}$$

Thus, if the input of the measuring system's intermediate link is fed with a short signal, the remaining links are disconnected for this instant, and the signal is measured by means of the system, the result thus obtained can be used for correcting the measurements obtained from the system. The correction thus introduced is equal to the error due to the system's links which are involved in the transformation of the signal.

<u>External disturbances – random functions of time.</u> Let us examine the most characteristic case when external disturbances affecting the links of the measuring system are random disconnected functions of time. For this purpose let us find, by means of the methods developed in the theory of random functions [2, 3, 4], the expectation value and dispersion of the measuring system's output variable both for the case of measuring its input variable $x(t)$ and for the case of transforming the control signal $B_{0\mu}(t)$ in the links between μ and $\underline{n}$.

The output variable's expectation value of the measuring system whose input is fed with a random function $x(t)$ can be represented by the relation

$$M[y(t)]=k_p\,M[x(t)]+\sum_{i=1}^{n}k_i^*\left\{M[\Delta_{0i}(t)]+\sum_{j=1}^{m}\beta_{ij}M[Z_{ij}(t)]\right\}. \tag{11}$$

The dispersion of the same variable is

$$D[y(t)]=k_p^2\,D[x(t)]+\sum_{i=1}^{n}k_i^{*2}\left\{D[\Delta_{0i}(t)]+\sum_{j=1}^{m}\beta_{ij}^2 D[Z_{ij}(t)]\right\}. \tag{12}$$

Whereas in the case of the system's μ-th link receiving control signal $B_{0\mu}(t)$ the expectation value of the output variable is

$$M[B(t)]=k_{\mu n}\,M[B_{0\mu}(t)]+\sum_{i=\mu}^{n}k_i^*\left\{M[\Delta_i(t)]+\sum_{j=1}^{m}\beta_{ij}M[Z_{ij}(t)]\right\}+M[\varepsilon(t)]. \tag{13}$$

The dispersion of the same variable is

$$D[B(t)]=k_{\mu n}^2\,D[B_{0\mu}(t)]+\sum_{i=\mu}^{n}k_i^{*2}\left\{D[\Delta_i(t)]+\sum_{j=1}^{m}\beta_{ij}^2 D[Z_{ij}(t)]\right\}+D[\varepsilon(t)]. \tag{14}$$

By performing with the thus found statistical characteristics of the system's output variable operations similar to those carried out in (3), (6) and (8) we shall find by means of the control signal method a corrected expectation value of the system's output variable:

$$M[y(t)]-M[\bar{\Delta}_c(t)]=k_p M[x(t)] \pm \sum_{i=1}^{\mu-1} k_i^{*}\left\{M[\Delta_{0i}(t)]+\sum_{j=1}^{m} \beta_{ij} M[Z_{ij}(t)]\right\}+$$
$$\sum_{i=\mu}^{n} k_i^{*}\left[M[\Delta_{0i}(t)]-M[\bar{\Delta}_{0i}(t)]+\sum_{j=1}^{m} \beta_{ij}\left\{M[Z_{ij}(t)]-M[\bar{Z}_{ij}(t)]\right\}\right]+M[\varepsilon(t)]. \tag{15}$$

The above expression determines, as we know from [3], the relation between the systematic components of the error. Hence, in analyzing (15) it is possible to verify that if the system's μ-th link is fed with a control signal and condition (9) is met, the value of the system's output variable can be corrected by the amount of the systematic component of the error which arises in the section of the system between links μ and $\underline{n}$. Since the latter error normally represents the greater part of the system's total error, such a correction obviously leads to an improvement in the accuracy of the system under complicated operating conditions.

In order to determine the measuring system's random error with the application of the control signal method, let us transform expressions (12) and (14) in a manner similar to that of (3), (6) and (8). A correct value for the dispersion of the measuring system's output variable will then become

$$D[y(t)]-D[\bar{\Delta}_c(t)]=k_p^2 D[x(t)]+\sum_{i=1}^{\mu-1} k_i^{*2}\left\{D[\Delta_{0i}(t)]+\sum_{j=1}^{m} \beta_{ij}^2 D[Z_{ij}(t)]\right\}$$
$$+\sum_{i=\mu}^{n} k_i^{*2}\left[D[\Delta_{0i}(t)]-D[\bar{\Delta}_{0i}(t)]+\sum_{j=1}^{m} \beta_{ij}^2\left\{D[Z_{ij}(t)]-D[\bar{Z}_{ij}(t)]\right\}\right]+D[\varepsilon(t)]. \tag{16}$$

In analyzing the above expression it can be verified that the random error of the measuring system's output variable can be corrected by means of a control signal by the value of the random error arising in the system's section between links μ and $\underline{n}$.

Example. A measuring system whose block schematic is shown in Fig. 2 is used for measuring liquid pressure in machines.

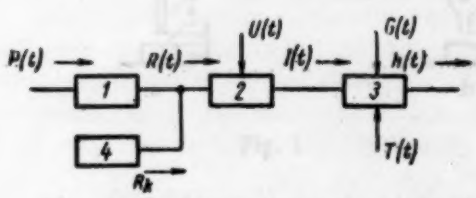

Fig. 2

The measuring system consists of a potentiometric pressure transducer 1, measuring circuit with a source of supply 2, and a moving coil galvanometer of oscilloscope 3. The measuring system's links are affected during operation by various external disturbances.

The control signal method is used for correcting this error when the measuring results are processed. For this purpose the input of the system's link 2 is periodically connected to link 4, which consists of an ohmic resistor made of material with a low temperature resistance coefficient. The measuring system is linear, with $k_p = 1 \dfrac{\text{kg-wt/cm}^2}{\text{mm}}$.

Resistance 4 is selected in such a manner that when connected to link 2 instead of transducer 1, $h_{ko} = 50$ mm, providing the system's links are not affected by external disturbances.

When the system was used for measuring pressure under one of the working regimes, a reading of $h_p = 75$ mm was obtained.

Without a correction the measured pressure is

$$P = k_p h_p = 1 \frac{\text{kg-wt/cm}^2}{\text{mm}} \cdot 75 \text{ mm} = 75 \text{ kg-wt/cm}^2.$$

When this pressure was measured the system was affected by the external disturbances described above. When resistance 4 was connected periodically for brief periods to the system instead of transducer 1 the deflection at the system's output was $h_k = 53.5$ mm.

For applying the correction let us use (10). The corrected value of pressure thus becomes

$$P = 75.0 - 53.5 + 50.0 = 71.5 \text{ kg-wt/cm}^2.$$

CONCLUSIONS

1. The accuracy of a complex measuring system which consists of several links connected in series and is subjected in its operation to the effect of a number of random external disturbances can be considerably improved by using with the system a special device which periodically supplies a signal to the input of one of the intermediate links of the system.

2. When a control signal method is used, the system's accuracy is raised by introducing a correction for the error arising in the part of the system which consists of the links involved in the transformation of the control signal.

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WIDE-RANGE PNEUMATIC INSTRUMENT FOR AUTOMATIC CHECKING OF DIMENSIONS

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The most promising instruments for automatic checking of the dimensional parameters of components during machining consist of non-contact pneumatic measuring devices, whose application, however, is limited to a narrow measurement range.

A new pneumatic measuring system with wide measuring limits has been investigated experimentally at the Moscow Machine-Tool Construction Institute.

In existing pneumatic measuring instruments (Fig. 1a) the air is fed under a constant excess pressure through input nozzle 1 to measuring chamber 2 and then to the atmosphere through measuring nozzle 3 and gap z. The measuring chamber pressure serves as a measure of the variations in the dimensions of tested component 4, and is read off instrument 5. In the new circuit (Fig. 1b), however, the air is fed under constant pressure through adjusting nozzle 1, which serves for final tuning of the instrument, to input nozzle 2, thence directly into measuring nozzle 3 and into the atmosphere through gap z, without passing through measuring chamber 5. The measuring chamber pressure in this instance also serves as a measure of the tested component 4, and is read off instrument 6.

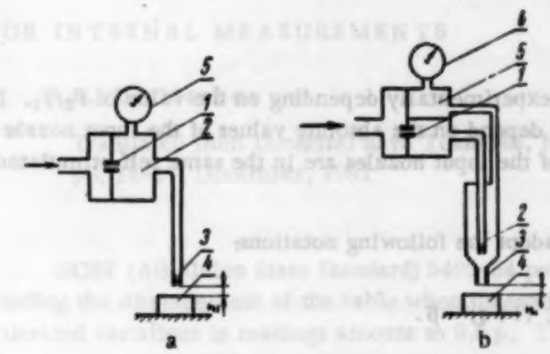

Fig. 1

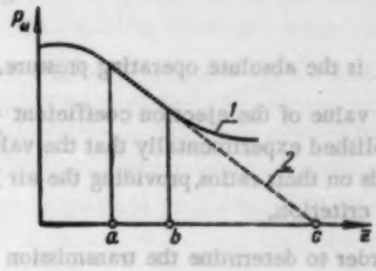

Fig. 2

Thus, in the former design the whole of the air was driven from the input nozzle into the chamber, in the latest design only part of it enters the chamber. For certain gaps the jet of air flowing out of the input nozzle provides such suction in the measuring chamber that even negative pressures can be established there.

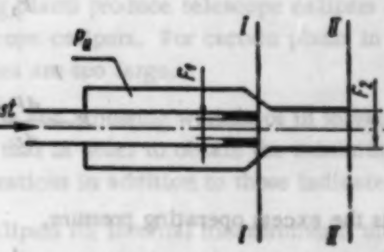

Fig. 3

Fig. 2 shows the characteristic curves of the relation between the measured pressure P_u and the gap z. Curve 1 represents the pneumatic system shown in Fig. 1a, and gap ab corresponds to the linear section of the curve and determines the instrument's measuring range.

Curve 2 represents the pneumatic system of Fig. 1b. Gap ac corresponds to the linear section of the curve and determines the considerably larger measuring range attained without loss of sensitivity. This effect can be explained theoretically by applying the hydrodynamic theorem of pulses to cross sections I − I and II − II (Fig. 3).

$$P_u = \frac{1}{F_2}\left(\frac{G_1+G_2}{g}\,W_2 - \frac{G_1}{g}\,W_1 + F_2P_a + \Delta R\right). \tag{1}$$

where G_1 is the rate of flow of air by weight through the input nozzle; W_1 is the speed of air flowing out of the input nozzle; G_2 is the rate of flow by weight of the ejected air; W_2 is the speed of the air flow through the measuring nozzle; F_1 is the area of the input nozzle orifice; F_2 is the area of the measuring nozzle orifice; for linear measurements $F_2 = \pi d_2 z$ (d_2 is the diameter of the measuring nozzle); P_a is the absolute atmospheric pressure; P_u is the absolute measured pressure; ΔR is the additional pressure on the walls of the measuring nozzle collector (henceforth we shall assume that $\Delta R = 0$, since it is very small); g is the acceleration due to gravity in freely falling bodies.

By substituting in (1) the values

$$G_1 = W_1 F_1 \gamma_1, \quad W_2 = \frac{G_1 + G_2}{F_2 \gamma_2},$$

and by denoting $G_2/G_1 = q$, performing the required operations and assuming that air is not compressible, we obtain the following approximate formula for calculating P_u in terms of the gap:

$$P_u = P_a - \frac{W_1^2 \gamma_1}{g} \left[\frac{F_1}{F_2} - \frac{F_1^2}{F_2^2} (1+q)^2 \right], \tag{2}$$

where according to our assumption $W_1 = \sqrt{2g(P_o - P_u)/\gamma_1}$.

We then obtain

$$P_u = \frac{2P_o \left[\frac{F_2}{F_1} - (1+q)^2 \right] - \frac{F_2^2}{F_1^2} P_a}{2 \left[\frac{F_2}{F_1} - (1+q)^2 \right] - \frac{F_2^2}{F_1^2}}, \tag{3}$$

where P_o is the absolute operating pressure.

The value of the ejection coefficient q is determined experimentally depending on the value of F_2/F_1. It has been established experimentally that the value of q does not depend on the absolute values of the input nozzle areas, but depends on their ratios, providing the air jets flowing out of the input nozzles are in the same self-stimulated region of the Re criterion.

In order to determine the transmission ratio K, let us adopt the following notations:

$$\frac{F_2}{F_1} = x; \; x = \frac{4d_2}{d_1^2} \cdot z; \; (1+q)^2 = \beta.$$

Then

$$K = \frac{dP_u}{dz} = \frac{dP_u}{dx} \cdot \frac{dx}{dz} = \frac{H(2x^2 - 4\beta x)}{2x - 2\beta - x^2} \cdot \frac{4d_2}{d_1^2} \tag{4}$$

where H is the excess operating pressure.

It is recommended that the distance l (Fig. 4) between the outlet face of the input nozzle and the inlet of the measuring nozzle be made equal to $l = 0.3 - 0.5\, d_1$.

For larger values of l the system works unsteadily. This is due to the fact that the cross section of the air jet flowing out of the input nozzle increases and thus carries more air to the measuring nozzle than it can handle for the given conditions. Hence, part of the air must flow back, forming eddy currents in the input section of the measuring nozzle.

Let us note that the flat end of the measuring nozzle produces a sudden change in the pressure at certain measurement gaps, i.e. it produces an adiabatic compression which should be prevented by leveling the end of the measuring nozzle (see Fig. 4).

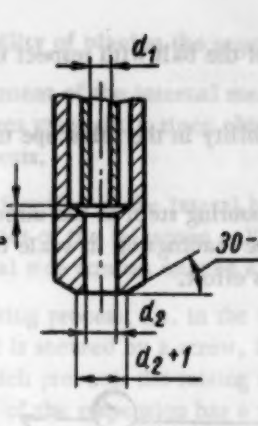

Fig. 4

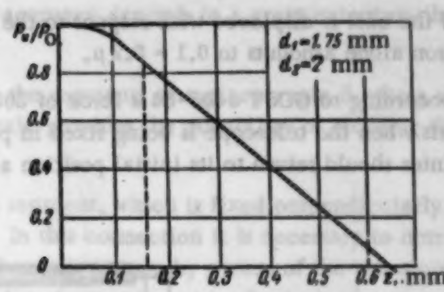

Fig. 5

CONCLUSIONS

The testing of the system showed that the linear measurement range for 2 mm nozzles amounted to 440 μ with a maximum gap of 600 μ (Fig. 5).

Thus, the measuring range completely covers the allowance for grinding, and instruments made according to this design can be used for non-contact automatic measurement during machining.

REPAIR AND ADJUSTMENT OF TELESCOPE CALIPERS FOR INTERNAL MEASUREMENTS

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GOST (All-Union State Standard) 5405-54 provides for variations in the telescope caliper readings of 1 μ including the displacement of the table when measuring by means of arcs. For a constant position of the table the tolerated variations in readings amount to 0.5 μ. The manufacturing plants produce telescope calipers according to these requirements. The same requirements apply to repaired telescope calipers. For certain plants in the ball-bearing and other branches of the engineering industry such tolerances are too large.

The experience gained by the Tomsk optico-mechanical repair and adjusting workshops in servicing the plants of the Tomsk Sovnarkhoz (Council of National Economy) has shown that in order to obtain the minimum deviation in readings of the repaired sets it is necessary to carry out certain operations in addition to those indicated in [1].

It is possible to raise the stability of the repaired telescope calipers for internal measurements up to 0.3 μ, including the movement of the table. This can be attained by raising the metrological characteristics of the telescope tube, improving the smoothness of the table movement and reducing the measuring effort.

Telescope tube. The tolerance of a repaired telescope tube reading amounts to 0.2 μ. Instruments which require increased stability should not be fitted with such tubes. Any differences in tube readings due to their locking should not produce any noticeable displacement of the pointer with respect to a scale marking.

For this purpose it is necessary to pay attention to two factors.

There should be no play in the key of the telescope tube measuring stem, since the bearing ball pressed into the key is not strictly central with respect to the axis. If there is any play, the point of contact of the ball with the

mirror pivot will describe a circle of a radius equal to the displacement of the ball with respect to the axis, thus producing variations in the displacement angle of the mirror.

If the ball is displaced with respect to the axis by 0.1 mm the instability in the telescope tube readings due to this reason alone amounts to $0.1 - 0.2\,\mu$.

According to GOST 5405-54 a force of 200 g-wt exerted on the measuring stem in the direction perpendicular to its axis when the telescope is being fixed in position should not alter the readings on its scale by more than $0.5\,\mu$. The pointer should return to its initial position after the withdrawal of this effort.

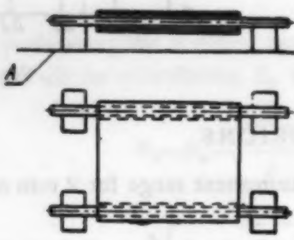

Fig. 1

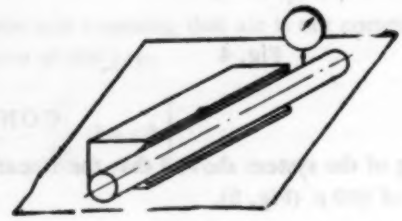

Fig. 2

A tube with an error obtained by pressing against it and amounting to $0.5\,\mu$ should not be fitted to an internal measurement instrument required for highly stable measurements.

For precision instruments the telescope tube should have deflections from its readings not exceeding $0.2 - 0.3\,\mu$ when a pressure of 200 g-wt is exerted against it, and its pointer should return to its initial position. This is attained by manual reaming of the bushing with subsequent lapping-in of the measuring stem. The stem should not be chromium-plated since this would prevent a high-quality fit.

Floating table. The turning of the cam should move the table easily and smoothly along its triangular groove guides. This is attained by lapping the guides and selecting bearing balls for each side with diameters differing by less than $0.2\,\mu$. The surface finish of the guides must not be inferior to grade 10, and the axes of the guides must be in the same plane and parallel to one another. The parallelism of the middle strip guide is checked by means of pins which are made not to be tapering or ovaloid (Fig. 1).

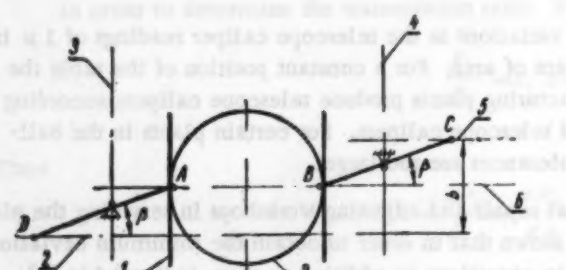

Fig. 3. 1) Gauge block; 2) tail spindle axis; 3 and 4) snap-gauge rotation axis; 5) telescope caliper axis; 6) measurement axis; 7) ring.

Four block gauges of the same size are placed on plate A. The middle strip with its pins is made to rest on them. Deviations from parallelism are determined by means of a measuring head with a calibration of 0.001 mm.

The checking of the position of the side-strip guide axes with respect to the base plates is made clear in Fig. 2.

The lack of parallelism in the guides produces varying friction forces during the movement of the table, thus providing additional stresses owing to the skewing of the axes.

Device for internal measurements. According to the manufacturing plants' specifications and the Committee's Instruction 108-55, the displacement of the tail-spindle tip axes and the telescope tube may attain 0.5 mm. A separate checking of the coaxiality of the holders and measuring segments is not provided.

The fitting holes of the holders and the suspension axles for the measuring segments provide their own errors due to lack of perpendicularity.

The adjustment of devices for internal measurements is carried out by means of lateral bearings in the holders. The segments are adjusted in a single plane until the tips A and B coincide along the axis of measurement as shown in Fig. 3, where b is the displacement of the telescope caliper axes with respect to those of the tail spindle, β is the angle between the segments and the measurement axis.

The possibility of placing the segments at an angle β is attained by making the suspension axle barrel-shaped.

The adjustment of the internal measurement devices by means of lateral bearings is a labor-consuming operation which requires great skill, since obtaining high measurement accuracy depends to a great extent on the operation of the segments.

The main function of the lateral bearings consists in setting the segments at a given angle β whose value depends on the peculiarities of the telescope caliper. The barrel-shaped axle provides the possibility of securing the segment without additional side stresses only in a static position.

In the locking process, i.e. in the movement away from the segment, which is fixed perpendicularly to the suspension axle and is secured by a screw, lateral stresses will arise. In this connection it is necessary to note a constructional defect which prevents the raising of the stability of internal measurements by means of the telescope caliper, namely the axle of the suspension has a thread which in the majority of cases increases the lack of perpendicularity of the axle with respect to the measuring segment plane of movement.

We decided to avoid using lateral bearings for setting the segment at angle β (Fig. 3). For this purpose the segment is cut if necessary along line A (Fig. 4). The lower part is adjusted and rigidly fixed to the upper in a position where the tips are fixed along the line of measurement.

The barrel-shaped axle is then replaced by a fixed cylindrical axle (Fig. 5).

The diameter of the cylindrical axle must be 0.03 - 0.05 mm larger than that of the fitting semi-circular opening in the segment for the purpose of increasing the rigidity of the fixing.

The appearance after lengthy use of the smallest play in the suspension axles can easily be eliminated by an axial displacement of the external races in the radial-thrust bearings.

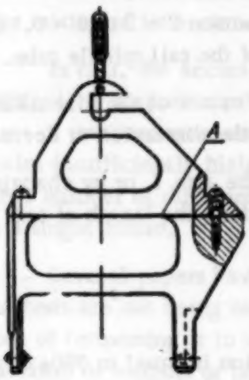

Fig. 4

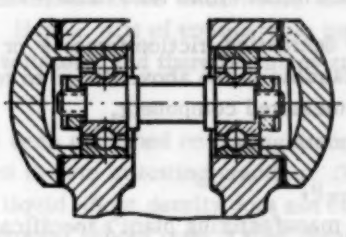

Fig. 5. Securing of the modified axle assembly for suspending the segment.

Since the segments are supplied individually for each telescope caliper, their initial adjustment at an angle β (Fig. 3) will hold. The removal of segments from their axles and their replacement do not alter the initial adjustment.

Such experiments have been carried out by us on two telescope calipers with satisfactory results.

One of the instruments has been in continuous use at the GPZ-5 plant for more than 9 months. The initial stability (variation) of readings has not changed and remains within the range of 0.3 μ including the movement of the table. The second instrument is in use at the V. V. Vakhrushev Electromechanical Plant. Neither instrument has been repaired or readjusted during 9 months.

Misgivings that, due to the absence of bearings, the rigidity of the segments would be insufficient to resist lateral stresses produced by transverse displacement of the table were not confirmed in practice.

Horizontal telescope calipers, according to their specifications, can measure internal diameters between 13.5 and 150 mm. For many plants in our industry and especially ball-bearing plants, it is important to extend the lower end of the range.

Experience gained in repair and adjustment work ("Kalibr" Plant Tomsk Sovnarkhoz, and others) has shown that it is possible to make special segments by means of which internal measurements can be started at 7-8 mm.

The manufacturing plants should adopt the production of such segments and make them on orders from our industry.

The instability of telescope calipers in internal measurements is caused by the lack of the locking lever lifting springs in the instruments now being produced. Such a spring should be incorporated. It can be easily designed and will not involve any considerable expenditure.

It is especially difficult to attain reading stability of 0.1-0.2 μ in the displacements of the table by a cam, owing to the inevitable defect inherent in the kinematics of the segment operation.

It will be seen from Fig. 6 that when the telescope caliper table is tilted by the cam the measuring tips in their displacement along the race or the gauge block provide a minimum reading of dimensions in two movements, namely from position 1-1 to position 0-0, and from position 2-2 back to 0-0. In these movements the friction forces F produce a torque $Tq = Fl$, where l is the arm.

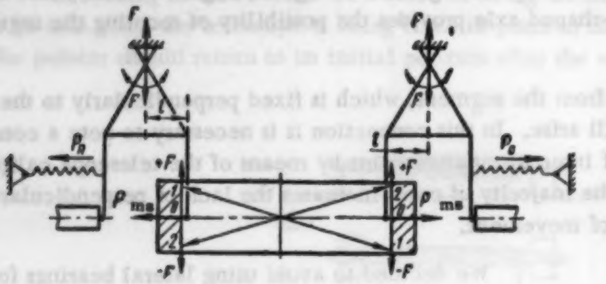

Fig. 6

When the tip is displaced from 1 – 1 to 0 – 0, friction force F produces in the telescope caliper segment a torque Tq in the anticlockwise direction, i.e. the segment will tend to turn in the direction of the telescope tube. At the same instant the tail spindle segment is subjected to a similar friction force F which produces torque Tq in the anticlockwise direction, i.e. the segment tends to turn in the direction of the telescope tube.

In the movement from position 2 – 2 to 0 – 0, the torques will be the same in magnitude but in the opposite direction, i.e. in the direction of the tail spindle tube.

When the table is tilted by the cam there can be no zero stability owing to the very nature of the kinematic operation of the segments, since both torques due to friction forces either tend to increase the dimension or decrease it.

A higher reading stability can be attained either by decreasing friction forces F or the arm l, or by changing the principle of operation of the segments. It is hardly desirable in the above design to reduce the length of arm l, since this will involve a reduction in the thickness of the measured component.

The friction force is

$$F = P_{ms}\mu,$$

where P_{ms} is the measuring effort, which according to the manufacturing plant's specification is equal to 300± 50 g-wt; μ is the sliding friction coefficient, which depends directly on the surface finish of the measured component.

Experiments have shown that with a grade 12-13 surface finish the instability of readings due to the movement of the table by the cam does not exceed 0.1 μ, for a grade 10 finish it rises to 0.2 μ, and for a grade 8-9 finish it reaches 0.3-0.4 μ.

In order to raise the stability of readings it is necessary to reduce the measuring effort P_{ms} to that adopted for the majority of instruments, i.e. to 200 ± 20 g-wt.

When the table is tilted by a cam, the segment cannot be displaced together with the component, since the turning of the cam is made according to the readings of the telescope caliper varying not more than ±5 μ from the actual size, and the sliding friction force will then be considerably smaller than the measuring effort of 200 g-wt. Thus, for a measured component weighing 3-4 kg the sliding friction force does not exceed 80-90 g-wt.

The effect of torque Tq can be reduced and the friction force eliminated by changing the kinematics of the segment operation.

In principle it is possible to replace the displacement of the segments about the suspension axle by their displacement parallel to the telescope caliper axis, but this is unlikely to be simpler than the use of the latest holders and segments with our design alterations.

CONCLUSIONS

It is not advisable to raise the technical requirements specified for horizontal instruments by GOST 5405-54, since for the majority of plants a reading stability of 1 μ is sufficient.

We recommend that the manufacturing plants incorporate a locking lever raising spring, adopt a holder design without lateral bearings but with segments and axles as shown in Figs. 4 and 5, develop the manufacture of additional couples of measuring segments to provide the possibility of measuring internal dimensions starting at 7-8 mm.

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MEASUREMENTS OF MASS

METHOD FOR CHECKING AREOMETERS IN A SINGLE LIQUID

M. D. Ippits and M. I. Tyutikova

Translated from Izmeritel'naya Tekhnika, No. 12,
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In calibrating and checking an areometer it is necessary to prepare a large number of solutions for checking its scale by freely dipping the areometer into each solution up to the tested graduation. The density of the solution is determined by reference or standard areometers if a comparison measurement method is used, or by hydrostatic weighing in the solution of a body if the areometers are being calibrated.

The requirement to use a large number of solutions is an essential drawback of this method and limits the further raising of its accuracy.

In fact, the accuracy of the above method can be raised by increasing the number reference and, which is particularly important, of standard areometers, whose calibration in the long run becomes an impractical task. At present a set of standard areometers consists of 69 instruments; however, their accuracy for certain portions of the scale still remains insufficiently high. Hence, it is of considerable interest to develop checking methods which do not require a large number of different solutions, and therefore many standards, and in particular a method of checking areometers in a single liquid.

Several papers have been published on testing areometers in a single liquid (usually water); however, these methods are not being used to date in testing practice. One method consists in adding to the areometer, for the purpose of immersing it in a liquid whose density does not correspond to the point on the scale being tested, a load (in the form of weights or pontoons), whose mass is then determined. Testing by this method is inconvenient, since for each tested point it is necessary to make preliminary calculations and preparations (or adjustments) of the required loads (pontoons), and then to determine their mass and volume.

Another method used in 1913-1914 in the Central Bureau of Weights and Measures consists in weighing the areometer in water when it is immersed consecutively to each tested point of the scale. However, the weighing of an areometer in water is not reliable owing to the large effect on the scale readings of the cohesive force between the areometer rod and the water surface layer.

In 1949 the same method was used by the National Physical Laboratory (Britain) with water having been replaced by xylene as a testing liquid. The use of xylene made it possible to obtain a good reproducibility of test results over a large portion of the scale, but tests were only carried out for liquids with a small surface tension and for areometers calibrated in 0.0005 and 0.0002 g/cm^3.

In order to raise the accuracy of checking areometers the VNIIM (All-Union Scientific Research Institute of Metrology) carried out work for further improving this method and its introduction into testing practice. The object of this work consisted in providing the required accuracy of testing for all types of areometers, including existing reference densimeters, and for any liquid, and in the first place for alcohol and sea water.

The essence of this method consists in transferring the unit of density from a standard areometer calibrated for one definite liquid to areometers with different ranges. The transfer is accomplished in a single liquid by means of the weighing method, namely, the density of liquid which corresponds to the tested point on the scale is determined by weighing the areometer in air and in that liquid by immersing it up to the aforementioned point. The immersion of the areometer is changed by varying the height of its suspension from the balance. From the weighing results the loss of weight in the areometer is determined and is equal to the weight of liquid which it has displaced. The volume of the liquid which is equal to the part of the volume immersed up to the tested point can be determined providing its density is known, and knowing the mass of the areometer it is possible to determine the density of the liquid in which the areometer would immerse up to the tested point.

In determining the density of the liquid by the above method it is necessary to take into account the effect of the air and of the liquid mass in the meniscus around the areometer stem. The equations for balanced scales in weighing the areometer in air, in a selected liquid at a normal temperature $\underline{t}$, and freely submerged in the liquid at the same temperature are respectively the following:

$$\left.\begin{aligned} & m-(V_{t'}+v)\,e=M\left(1-\frac{e}{\delta}\right) \\ & m-V_tD_t+a-ve_1=M_1\left(1-\frac{e}{\delta}\right) \\ & m-V_t\varrho_t+a'-ve_2=0 \end{aligned}\right\} \qquad (1)$$

where $\underline{m}$ is the areometer mass; V is the areometer volume up to the testing mark; $\underline{v}$ is the volume of the unsubmerged part of the stem; ρ_t is the density of the liquid in which the areometer is freely immersed up to the tested mark at a normal temperature of $\underline{t}$; D_t is the density of the liquid in which the areometer is weighed at the same temperature $\underline{t}$; M is the mass of weights which balance the areometer in air; M_1 is the mass of weights which balance the areometer placed in a selected liquid; δ is the density of the weights; e, e_1 and e_2 are the densities of air when the areometer is weighed in air, in a liquid and in free immersion respectively; $\underline{a}$ is the mass of the meniscus around the areometer stem when it is weighed in a selected liquid of density D_t; a' is a similar mass when the areometer is freely immersed in a liquid of density ρ_t; t' is the air temperature when the areometer is weighed in air.

The values of ve, ve_1 and ve_2 differ from each other very little, since the variations in the volume of the stem and the density of air produce small variations in the weight of the areometer, which do not affect the readings. Hence the values of ve_1 and ve_2 can be equated to the value of ve.

The term $V_{t'}e$ in the first equation can be replaced by $V_t[1+(t'-t)\beta]e$ or approximately by V_te, since the values of β (temperature expansion coefficient of glass, equal to 0.000025) and $\underline{e}$ are small.

Having made the above substitution and subtracted the second and third equations from the first we obtain a system of two equations of the form

$$V_t(D_t-e)=M\left(1-\frac{e}{\delta}\right)-M_1\left(1-\frac{e_1}{\delta}\right)+a$$

$$V_t(\varrho_t-e)=M\left(1-\frac{e}{\delta}\right)+a',$$

whose solution with respect to ρ_t after certain operations results in

$$\varrho_t=\frac{(D_t-e)\left(M+\dfrac{a'}{1-\dfrac{e}{\delta}}\right)}{M-M_1\dfrac{1-\dfrac{e_1}{\delta}}{1-\dfrac{e}{\delta}}+\dfrac{a}{1-\dfrac{e}{\delta}}}+e.$$

The values of $a'/[(1-(e/\delta)]$ and $a/[(1-(e/\delta)]$ differ but little from the value of a' and $\underline{a}$ and can be substituted by the latter, and factor M_1 approaches unity when the areometer is weighed in the liquid immediately after having been weighed in air. Thus the above formula becomes

$$\varrho_t=(D_t-e)\,\frac{M+a'}{(M-M_1)+a}+e. \qquad (2)$$

Formula (2) has been derived on the assumption that temperature $\underline{t}$ of the liquid is equal to the normal temperature of the areometer. It has been established that the measurement results do not change if the weighing of the areometer is made at any liquid temperature, providing that the tested and standard areometers have the same normal temperature and the same expansion coefficients, i.e. if they are made of the same type of glass. In this case

the value of D_t in (2) will denote the readings of the reference (standard) areometer instead of the actual density of the liquid, i.e. the required density in this instance will be determined in the same manner as for the normal temperature of the liquid.

Thus, in checking an areometer by the above method it is necessary to determine the weight M of the areometer in air, the loss in weight $(M-M_1)$ when the areometer is immersed in the liquid up to each tested mark of the scale, the density D_t of the liquid in which the areometer is weighed, and density e of air.

Thus it becomes possible to check the whole areometer scale in the same liquid. The density of this liquid is measured by a standard or reference areometer which is immersed simultaneously with the tested areometer. For checking standard densimeters special areometers were made with calibrations of 0.000015 g/cm³ (only for a selected liquid) and certified with a maximum error of $3 \cdot 10^{-6}$ g/cm³.

The liquid used for testing should be selected to produce the least possible braking effect on the scale beam oscillations in weighing the areometer. For this purpose it should have a small surface tension and must not be viscous. Moreover, it must be transparent, since many areometers are calibrated for a reading at the bottom edge of the meniscus.

Among the liquids used in areometry these requirements are best met by benzene. Benzene is a single component liquid; it does not change its density in evaporating, it has a small surface tension and low viscosity. The aforementioned standard areometers were made for this liquid in density ranges from 0.8766 to 0.8772 and from 0.8785 to 0.8795 g/cm³.

The value of a' which is included in (2) is calculated from the expression

$$a' = \alpha \pi \rho d, \tag{3}$$

where α is the capillary constant of the liquid for which the areometer is calibrated; ρ is the density of the liquid which corresponds to the tested mark of the scale; d is the diameter of the areometer stem for a given scale mark.

The value a is calculated from the formula with α and ρ taken for the liquid in which the areometer is being tested, i.e. for benzene. It is possible to compute in advance a table giving the values of a for the required α, ρ, and d.

For checking areometers by the new method an instrument was installed which provided the required accuracy and reliability of measurements. The equipment consists of two basic parts, namely of hydrostatic balances and a thermostatic bath fitted with a TS-15 thermostat.

The accuracy of checking areometers by this method to a great extent depends on the characteristics of the balances and the conditions of weighing. The greatest error $\Delta\rho$ in determining density from (2) must satisfy the inequality

$$\frac{\Delta(\varrho-e)}{\varrho-e} < \frac{\Delta(D-e)}{D-e} + \frac{\Delta M}{M} + \frac{\Delta M + \Delta M_1}{M - M_1}. \tag{4}$$

The first term in (4) represents the relative error in determining the density of the testing liquid by means of the reference (standard) areometers. If these areometers are properly selected it will not affect the test results.* The basic error, however, is that due to weighing, namely, error ΔM_1, produced by weighing the areometer in a liquid, since the surface tension of a liquid prevents free oscillation of the beam, raises the readings' variations of the balances and decreases their sensitivity. In order to overcome surface tension it is necessary to use balances with a heavy beam which has a large restoring torque.

Moreover, the balances must possess a stable position of equilibrium, since the loss in areometer weight is determined with respect to the same position of equilibrium as that obtained in weighing the areometer in air. The balance should be placed in a position to avoid unequal heating or cooling, which would produce a displacement in its position of equilibrium.

* The accuracy of these areometers should be at least three times greater than that of the tested areometer.

A displacement in the equilibrium of the balance can also be produced by aerostatic forces which arise when the density of air changes and the volume of the loads on the pans is different. In order to avoid this effect the tested areometer is balanced by another areometer or a float of the same volume as the tested areometer.

The required characteristic of the balance is determined by the last term in (4) providing these conditions are maintained. For an areometer with a volume amounting to 100 cm³ weighed in benzene the value of $M-M_1$ will approach 90 g, i.e. for checking with an error of the order of $2 \cdot 10^{-5}$ g/cm³ it is necessary to have a ΔM_1 not exceeding 1 mg.

In the tests carried out by the VNIIM 1 kg balances with a bronze beam were used. The balance for weighing the areometer in air was calibrated in 0.5 mg and for weighing it in benzene in 2.0 mg; the variation in balance readings in either case did not exceed 0.5 of a calibration. This provided an evaluation of density with a maximum error of $2 \cdot 10^{-5}$ g/cm³ for densimeters of a working standard type.

The accuracy in checking areometers also depends on a constant liquid temperature. In view of the fact that the temperature of the liquid used for weighing the areometer can have, as was pointed out, any value and the density of the liquid at each weighing is checked by an accurate areometer, it is sufficient to provide a temperature which is constant within the limits of 0.01°C only for the duration of each weighing, thus making the problem much easier.

Areometer number	Tested point on the scale	Mean corrections, g/cm³			Discrepancies in corrections, g/cm³
		new method		control method	
		observed	corrected		
2	0.970	+0.00015	+0.00014	+0.00014	0
2	0.972	+0.00014	+0.00013	+0.00012	0.00001
2	0.974	+0.00013	+0.00007	+0.00007	0
2	0.976	+0.00012	+0.00005	+0.00005	0
2	0.978	+0.00014	+0.00008	+0.00008	0
2	0.980	+0.00025	+0.00018	+0.00016	0.00002
5	0.980	−0.00015	−0.00022	−0.00020	0.00002
5	0.982	−0.00006	−0.00012	−0.00010	0.00002
5	0.984	+0.00004	−0.00003	−0.00002	0.00001
5	0.986	+0.00013	+0.00005	+0.00006	0.00001
5	0.988	+0.00020	+0.00012	+0.00011	0.00001
5	0.990	+0.00026	+0.00018	+0.00017	0.00001
6	0.990	+0.00039	+0.00031	+0.00032	0.00001
6	0.992	+0.00040	+0.00032	+0.00034	0.00002
6	0.994	+0.00041	+0.00032	+0.00031	0.00001
6	0.996	+0.00044	+0.00035	+0.00033	0.00002
6	0.998	+0.00047	+0.00047	+0.00047	0

A constant liquid temperature is maintained by a thermostatic bath in which the cylinder with the benzene is placed. The bath is fitted to a carriage which runs along rails mounted below the balance. The height of the carriage and, hence, of the cylinder, can be adjusted.

For suspending the areometer to the balance pan a holder is used which consists of a frame containing a pulley and a block. A caprone thread is wound on the pulley and has a hook at one end for suspending the areometer by the loop cleat of its stem. It is possible by means of this holder to place the areometer in the liquid accurately against the tested mark of the scale.

The testing of the areometer is started with the determination of its mass by weighing it on one arm. The areometer is weighed in such a manner that the balance position of the beam for measurements in the air is displaced from its center position by 1-2 calibrations, so that the areometer pan is slightly lower than the other. The areometer

is then weighed with the same tare weight in a liquid. For this purpose the areometer is suspended by its cleat to the holder and immersed in the liquid so that when the beam is in the position corresponding to its balance in air the tested mark on the areometer scale and the liquid level roughly coincide.

The areometer scale is read in the place where it intersects with the liquid level in the following manner: a slightly larger quantity of weights than necessary for balancing the areometer immersed in the liquid is placed on the balance pan from which the areometer is suspended. Next, the arrest is gradually released and the sighting line of the microscope (or the balance pointer) is set against the scale calibration which was observed in balancing the areometer in air. The scale of the tested areometer is read in this position of the arrest.

The loss of weight in the areometer is then determined with respect to the aforementioned position of equilibrium of the balance beam.

Thus, the checking of each scale marking after weighing the areometer in air amounts to a simple operation which consists of reading the areometer scale, determining its loss in weight and evaluating the density of benzene.

It is more convenient to start checking the areometer from the lowest mark on the scale. For checking subsequent marks the areometer is immersed deeper into the liquid up to the required number of divisions, and the required weights are added to bring the balance to the original position of equilibrium.

Areometers intended for liquids with density less than that of benzene can also be checked by the above method. In such a case an additional weight is attached to the areometer in order to overcome the ejective force of benzene.

By this method a set of 67 densimeters of the working standard type was calibrated in 0.0001 g/cm^3 over a density range from 0.65 to 1.84 g/cm^3.

In order to check the results thus obtained some of the areometers were checked by the hydrostatic weighing method used for certifying standard areometers. These tests have been carried out in various liquids, such as aqueous solutions of alcohol of various densities, and aqueous solutions of sulfuric acid. In all the instances, with the exception of a small portion of the scale used for measuring weak aqueous solutions of alcohol, the difference in corrections obtained by checking areometers by the new and by the control method did not exceed 0.2 division of the scale, i.e. they were within the accuracy limits of the control method of measurements.

The accuracy of measurements by the new method can be characterized by the maximum error in a series of measurements. The value of a maximum error calculated from repeated checking of each point on the scale of several areometers did not exceed 0.2 of a scale calibration. Thus the method of checking in a single liquid is not inferior to the hydrostatic weighing method used for testing standard areometers.

It is necessary to pay particular attention to the checking of areometers in weak aqueous solutions of alcohol in the range of densities of 0.970 to 0.996 g/cm^3. Over this range there is a discrepancy in the measurement results obtained by the new and the control method amounting to almost a whole division of the scale. It was found that this discrepancy is due to an incomplete wetting of the areometer stem in the above solutions. In fact in (2) the mass of the meniscus is determined on the assumption that a complete wetting of the areometer stem by the liquid is attained, i.e. that the angle of contact $\omega = 0$ and $\cos \omega = 1$. However, in aqueous solutions of alcohol with a large percentage of water full wetting does not take place, i.e. the angle of contact does not equal zero. This must produce a reduction in the corrections of the areometer readings, which has been confirmed experimentally.

From experimental results the values of $\cos \omega$ were determined. These evaluations are based on the fact that the difference in corrections evaluated experimentally can be established as the difference between density ρ calculated from (2) and density ρ_1 calculated from the same formula but with $\cos \omega$ taken into consideration. From the above formulas we obtain the following expression for determining $\cos \omega$:

$$\cos \omega = 1 - \frac{\varrho - \varrho_1}{(D-e)\,a'}\,[(M - M_1) + a]. \tag{5}$$

By means of these calculations two mean values were obtained for $\cos \omega$, namely 0.95 for a scale range of 0.970 to 0.972 g/cm^3 and 0.81 for a range of 0.974 to 0.996 g/cm^3.

The attached table shows the areometer test results obtained by the new method with the values of $\cos \omega$ taken into consideration for the range of weak aqueous solutions of alcohol.

Thus, the method of checking areometers in a single liquid can be extended to the whole scale of alcohol solutions; moreover, in the range of 0.970 to 0.996 g/cm^3 the observed results should be corrected by multiplying the alcohol meniscus mass which figures in the numerator of (2) by a coefficient of 0.81 or 0.95 according to the data given above.

CONCLUSIONS

1. The method of checking areometers in a single liquid is not inferior in accuracy to the method at present used for checking standard areometers.

2. It is no longer necessary to prepare a large number of liquid solutions, and hence to have a large set of standard areometers. It is sufficient to have as standards one or two high-precision areometers with a scale for a limited range of liquid densities.

3. The proposed method is simple, and requires less time to carry it out (by a factor of 4-6) than the reference method of hydrostatic weighing.

4. The application of this method for checking reference areometers will raise the accuracy of checking working areometers and will ensure that the error is kept within the limits of one scale division, which up to date has not been attained for certain instruments.

The raising of checking accuracy will make it possible to introduce into commercial use more accurate areometers than those existing at present, for instance, grade 0.05 alcohol-meters.

CHECKING TRUCK WEIGHBRIDGES

A. N. Maiskii

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The inclusion of Krever's method* in Instruction 15-52 does not completely solve the problem of effective state testing of truck weighbridges, especially in rural districts. Until the GKLs (State Inspection Laboratories) are supplied with reference measuring equipment developed by the Committee's institutes, optimum solutions of the problem will have to be sought, taking into consideration the increased production of weighbridges with a dial head.

We think that side by side with weight-checking trucks it is advisable to develop separate portable devices for mechanizing the loading and unloading of reference weights and the displacement of sets of these weights.

Instruction 15-52 specifies but one method for obtaining the metrological characteristics in state testing of truck weighbridges which are in use and have been repaired and reassembled, and specifies a single set of tolerances and one validity for the inspection stamp. If in testing a weighbridge results are obtained which approach the specified tolerances, it seems wrong to consider that weighbridge unsuitable for further service, yet if an inspection stamp is affixed to it there is no certainty that for the coming 2 years the weighbridge will preserve its properties. Therefore, it would appear better to establish validities for inspection stamps of 1 to 3 years, depending on the type of testing. This will increase, no doubt, the number of annual tests and will require a certain reorganization, etc. Yet the advantages of a differentiated validity of inspection stamps will raise the effectiveness of state testing.

Often truck weighbridges are not used up to their full capacity of 25 tons, and the owners ask to limit their checking up to 12-15 tons. In view of the known difficulties of checking large capacity weighbridges, it seems advisable to meet these requests and to develop simple stopping devices which could be used on a temporary basis to limit the displacement of the weight up to the tested mark on the scale.

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* See "Izmeritel'naya tekhnika" 1960, No. 3; 1961, Nos. 1, 7, and 10.

The manufacturing plants should be instructed, when submitting truck weighbridges for state testing, to supply with them specifications for their testing, taking into consideration the available testing equipment. This refers, particularly, to the 50-ton truck weighbridges with a dial head manufactured by the "Armalit" plant.

It would be desirable for readers of this journal to express their opinion regarding the above proposals.

MEASUREMENTS OF TIME

ELECTRONIC RELAY FOR A PRINTING CHRONOGRAPH

A. I. Yazev and Yu. V. Markov

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A transistorized pulse amplifier for printing chronograph 21P made by the ÉChL plant is described in [1]. This amplifier has to be used in order to reduce the input current which leads to a rapid burning of the clock contacts and of the transit instrument micrometer.

Without reconstructing the chronograph, its input current can be reduced in a much simpler manner by replacing the direct switching of the input recording circuit of the chronograph with switching through an electron tube which has a sufficiently small internal resistance. For this purpose a double triode 6N5S can be used (the two halves are connected in parallel). The input voltage fed to the chronograph terminals (about 50 v) is ample for supplying the anode circuit of the tube. A biassing voltage is fed to the grid through an external contact (for instance, a clock contact) in such a way that the blocking and unblocking of the tube switches the chronograph on and off by means of the anode current (Fig. 1). The input current will then consist of the very small grid current.

A disadvantage in the chronograph circuit consists of the use of an electromagnetic relay whose contacts switch in the winding of the printing or tape-propelling device. The large current (about 2 amp) burns the relay contacts, thus making the chronograph operation unstable.

Fig. 2 shows the circuit of an electronic pulse relay which can be mounted on the horizontal panel of the chronograph near the power transformer instead of the electrical circuit of the electromagnetic relay. Such an electronic

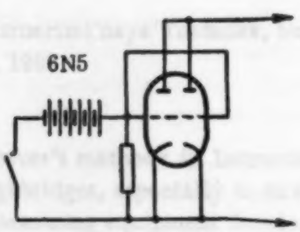

Fig. 1

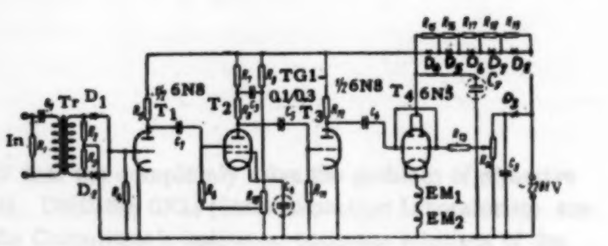

Fig. 2

relay can register voltage pulses of any polarity and switch on and off direct voltage at the input of the circuit. The secondary winding of the input transformer carries pulses which, having been rectified by the crystal diodes D_1 and D_2, are transformed into negative pulses and amplified by triode T_1. Positive pulses are fed from the anode of T_1 to the grid of the thyratron which becomes conducting. (Between the pulses the thyratron is blocked by the negative voltage obtained from potentiometer R_{10}.) When the thyratron is fired capacitor C_3 discharges through resistor R_8 and the thyratron, thus providing across its anode a negative pulse which extinguishes the thyratron. The width of the pulse thus formed depends to a great extent on the values of C_3 and R_8.

Triode T_3 reverses the phase of the pulse obtained from the thyratron anode and converts it into a positive voltage pulse required for tripping the output triode T_4 (6N5S). The cathode load of the latter consists of the tape-propelling and printing mechanisms' electromagnet windings which are rewound with a thinner wire and a greater number of turns. The negative bias voltage for T_4 is obtained by rectifying the mains voltage through diode D_3 (DGTs-27) and is controlled by means of potentiometer R_{14}.

The tube heaters are supplied from the chronograph power transformer with its secondary winding rewound. The anode voltage is obtained from the mains voltage rectified by means of diodes D_4, D_5, D_6, D_7, and D_8 (DGTs-24).

The electronic relay which has virtually no lag provides the highly stable operation of the printing chronograph and is very convenient for commutating pulses at the input of the device. The accuracy of recording time on a printing chronograph by means of an electronic relay is determined by the accuracy with which the chronograph can be read, i.e. it amounts to 0.001 sec.

The above relay has been produced and is being successfully used in the Time Service of the Irkutsk Astronomical Observatory.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

MECHANICAL MEASUREMENTS

DEFORMATION ERRORS OF PISTON MANOMETERS AT PRESSURES UP TO 10,000 kg-wt/cm²

M. K. Zhokhovskii and V. V. Bakhvalova

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 23-26, December, 1961

The experimental method for determining the difference of deformation errors in piston manometers and their comparison with the theoretically-calculated values for pressures up to 7,000 kg-wt/cm² is described in detail in [1]. Piston manometers with M. K. Zhokhovskii's [2] measuring multipliers fitted with high-pressure piston systems and normal cylinders as well as those with counter-pressure have been investigated. An indirect method of comparing manometers by means of a sensitive differential manometer [3] was employed in [1]. For nominally equal pressures, calculated on the assumption that the effective piston area of the compared manometers does not change with pressure, we determined the actual difference in pressures owing to the deformation of the piston systems. This difference was measured by a differential manometer and was then compared with calculations obtained from correction formulas [4].

Previous experiments have shown that the difference in the deformation errors of piston manometers at pressures up to 5,000-7,000 kg-wt/cm² virtually coincides with the calculated values. Discrepancies, as a rule, were of a random nature and insignificant. The comparison of piston systems with counter-pressure revealed a systematic although small discrepancy between the experimental and calculated pressure differences, which at the time could not be fully explained.

In the present work we are describing experiments in a range extended to 10,000 kg-wt/cm² and performed with a greater number of high-pressure piston systems.

Of the ten tested piston systems (four with normal and six with counter-pressure cylinders) we formed 16 combinations for mutual comparison. The cylinders of all the piston systems were made of 50khFA brand steel, and the pistons of ShKh15 and 50KhFA brands of steel. Since the components were made from the same billet it is possible to assume that the modulus of elasticity for each brand of steel was the same. The modulus of elasticity for each brand of steel was approximately determined experimentally. The method of comparing manometers was basically the same as in [1] with the following improvements.

1. The differential manometer was calibrated for each measurement of pressure differences. Measurements at each point and calibrations were repeated many times.

2. In order to eliminate systematic errors due to an inaccurate determination of the mass of weights and the initial values of the low-pressure pistons' effective areas, two series of experiments were conducted. In each series the high-pressure piston systems' places were interchanged in the manometers. The mean value of the two series of measurements was taken as the actual value of the pressure difference.

Basic experimental results are shown in Tables 1 and 2. Comparisons of similar piston systems using cylinders without counter-pressure (Table 1) produced good agreement between the calculated and experimental values of pressure differences. Any discrepancies over the entire pressure range in comparing three piston systems did not exceed 1 kg-wt/cm². The fourth piston system (XII/6) provided a discrepancy of 5 kg-wt/cm² at maximum pressure.

Tests of similar piston systems using cylinders with counter-pressure (Table 1) provided comparable results.

The mutual comparison of piston systems Nos. 5 and 7, however, revealed a considerable discrepancy between the experimental and calculated differences in deformation errors, amounting, at maximum pressure, to 18 kg-wt/cm². The comparison of systems Nos. 5 and 7 with other similar piston systems using counter-pressure has shown that the deviation of the deformation errors in comparisons with system No. 5 did not exceed 4 kg-wt/cm², whereas in the comparison with system No. 7 it reached 13-15 kg-wt/cm². It follows, therefore, that the considerable discrepancies are due to certain peculiarities of system No. 7.

TABLE 1

Nominal pressures, kg-wt/cm²	Differences in readings of similar piston systems, kg-wt/cm²																							
	systems using cylinders without counter-pressure										systems using cylinders with counter-pressure													
	X/3–8/3		8/3 – X/6		XII/6-X/3		8/3-XII/6		XII/6–X/6		IV/6–II/3		IV/6 – 1/6		IV/6–XIII/6		XIII/6–II/3		5–7		1/6–5		IV/6–7	
	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values	experimental	calculated values
2000	0.2	0	-0.8	0.1	-0.5	0.1	-0,1	+0,1	1,1	0	0,3	0,1	0	0,1	0	0	-0,1	0,1	—	—	+0,2	0	0,4	0,1
3000	0.2	0	-0.7	0.2	-0.7	0.2	-0,5	+0,2	1,6	0	0,4	0,3	0,5	0,2	0	0	0	0,3	—	—	+0,2	0	0,8	0,2
4000	0.2	0	-0.4	0.4	-0.8	0.4	-1,0	0,4	2,2	0	0,3	0,5	0,9	0,3	0	0	0,4	0,5	-1,0	0,4	-0,6	0,1	2,3	0,4
5000	0.2	0	-0.5	0.6	-1.0	0.7	-1,2	0,8	2,9	0	0,2	0,8	1,4	0,5	0,1	0	-0,9	0,8	-2,3	0,6	-1,4	0,1	5,1	0,6
6000	0.3	0	-0.2	0.9	-1.0	0.9	-1,6	0,9	3,6	0	0,4	1,1	1,8	0,7	0,3	0	-1,0	1,1	-5,1	0,8	-2,3	0,1	8,0	0,8
7000	0.4	0	+0.4	1.2	-1.4	1.3	-1,7	1,15	3,7	0	1,1	1,5	2,1	1,0	0,6	0	-1,2	1,5	-6,7	1,1	-2,4	0,1	9,8	1,1
8000	0.8	0	+1.2	1.6	-3.2	1.7	-2,2	1,6	3,4	0	1,4	1,9	2,1	1,3	0,9	0	-1,9	1,9	-9,3	1,5	-2,3	0,2	11,8	1,5
9000	0.8	0	+2.4	2.0	-1.7	2.1	—	2,0	5,0	0	1,9	2,4	1,7	1,6	1,8	0	-2,6	2,4	-13,5	1,9	-3,4	0,2	13,5	1,9
10000	1.1	0	—	2.5	-2.3	2.6	-2,5	2,5	—	0	2,3	3,0	2,2	2,0	2,6	0	-2,7	3,0	-16,2	2,3	-3,8	0,3	15,3	2,3

Since the material of the piston systems was the same, differences in the moduli of elasticity could not be the reason for the above discrepancies. Geometrically the systems differed only by the size of the outside cylinder. Hence, in order to preserve complete similarity in the experimental conditions, the diameter of cylinder No. 7 was reduced; however, this did not affect the discrepancies to any substantial degree.

It could only be assumed that the most probable cause for the discrepancies was a distortion in the shape of piston No. 7 and possibly its cylinder. It is known [4] that at high pressures there occurs a redistribution of pressure in the radical clearance of piston systems due to deformations and changes in the viscosity of liquids. Deviations from a cylindrical form of the piston and the cylinder bore produced during manufacture must, in turn, affect the nature of the flow in the clearance, thus producing an additional redistribution of pressure.

With an initial deviation of the cylinder from a cylindrical form any redistribution of pressure will lead to additional forces operating along its axis, unaccounted for by correction formulas.

In order to check the shape of the cylinders their diameters were carefully measured on a horizontal telescope caliper in steps of 5 mm in two mutually-perpendicular directions. Internal diameters of cylinders were not measured since they could not be reliably checked over the whole of their length owing to their small size. Measurements have shown that virtually all the cylinders had a distorted cylindrical form, some of the portions being slightly tapered, and those nearer to the upper part of the cylinder forming a collar. System No. 7 had a considerably larger collar than the rest, and the shape of the whole piston was greatly distorted. This, undoubtedly, is the reason for the considerable discrepancies between the measured and calculated deformation errors.

The remaining experiments with similar systems in this group reproduce completely the results obtained with piston systems using normal cylinders. The discrepancies in the greater part of instances attain 1-2 kg-wt/cm², and in certain cases do not exceed 5.5 kg-wt/cm² for maximum deformation errors in each system of 57 kg-wt/cm².

The discrepancies between the measured and calculated values for both groups of similar piston systems are not so large if one considers the possible effect of the distortions in the cylindrical form of pistons, which was convincingly confirmed by system No. 7.

TABLE 2

Nominal pressure, kg-wt/cm²	Differences in readings of dissimilar piston systems, kg-wt/cm²							
	XII/6–IV/6		8/3 – IV/6		X/6 – IV/6		8/3 – 1/6	
	experi-mental	calculated values	experi-mental	calculated values	experi-mental	calculated values	experi-mental	calculated values
2000	3.2	3.2	2.9	3.1	4.0	3.2	4.3	3.2
3000	7.4	7.2	7.9	7.0	8.4	7.2	9.0	7.2
4000	13.5	12.8	13.7	12.4	16.6	12.8	15.0	17.2
5000	19.7	20.1	19.9	19.4	22.6	20.0	22.7	19.9
6000	28.1	28.9	27.9	27.9	29.7	28.8	30.6	28.7
7000	35.8	39.3	37.6	38.0	38.9	39.2	39.2	39.0
8000	45.0	51.3	47.2	49.7	47.8	51.2	50.2	50.9
9000	55.0	65.0	55.3	62.9	55.2	64.8	60.2	64.4
10000	61.1	80.2	60.8	77.6	65.6	80.0	69.7	79.6

The comparison of dissimilar systems (using cylinders with and without counter-pressure) is shown in Table 2. It will be seen that the experimental values of the difference in pressures up to the order of 5,000-6,000 kg-wt/cm² are slightly higher, and that for higher pressures they become lower than the calculated values. For 10,000 kg-wt/cm² the difference in errors reaches 10-19 kg-wt/cm². Such discrepancies could be the result of an insufficiently rigorous theory or the failure to observe in the experiments all the required conditions.

In the experiments with similar systems these circumstances could not be observed because the compared systems were basically identical.

The theoretical conclusions [4] are based on the following assumptions.

1. The pressure distribution in the clearance has a smooth nature and the deformations of the piston and cylinder produced by it are represented by the Lamé equation.

2. The operating portion of the piston and the cylinder bore have a regular cylindrical shape.

3. The structural shape and dimensions of the cylinder as well as its sealing do not produce any appreciable additional deformations.

The first assumption was confirmed repeatedly by experiments [4] related to the speed of the piston travel, the distribution of pressure, etc. for different and varied conditions (different viscosities of liquids, dimensions and materials of piston systems).

The above-mentioned satisfactory agreement between the experiments and theory in comparing dissimilar systems up to pressures of 6,000-7,000 kg-wt/cm² also shows that the development of deformations is in agreement with Lamé's equation. In the absence of such an agreement one would have expected to find considerably larger discrepancies, since the tested piston systems differed from each other considerably in the magnitude and sign of their deformations. Moreover, the pressure distribution along the clearance could not have been linear at such high pressures.

It has been shown that a departure from the second assumption about the regular shape of the clearance can affect substantially the experimental results. The effect of this factor on the experiments under consideration will be dealt with at a later stage.

Let us now examine to what extent the third condition with respect to the structure and sealing of cylinders has been fulfilled. A cylinder without counter-pressure (Fig. 1) is only loaded by its internal pressure which is variable in the clearance and constant in the lower portion. A cylinder with counter-pressure (Fig. 2) is loaded in addition around its sides and its butt end. The shape of the bore in both cylinders is the same; its diameter changes rapidly both at the top and bottom end of the polished portion.

The method of sealing the cylinders in the body of the manometer differs; the cylinder without counter-pressure is tightened directly by a nut screwed on from the top, and the cylinder with counter-pressure is sealed by the method of an uncompensated area. The percentage of imbalance is small and the pressures in the rubber packing and the outside cylinder wall are close to each other.

The sealing of cylinders, deviations of their shape at the ends, and finally the presence of the cylinder butts produce only local departures from the regular cylinder deformations. Calculations show that these departures would not produce considerable deviations of the cylinder deformations from the calculated values, since they form only small portions of the total space.

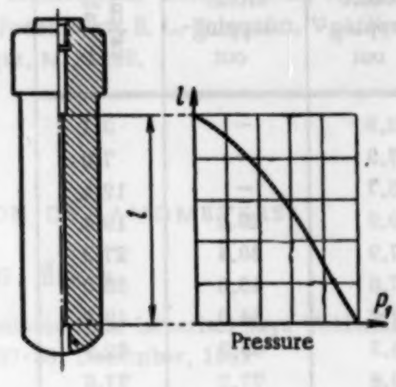

Fig. 1

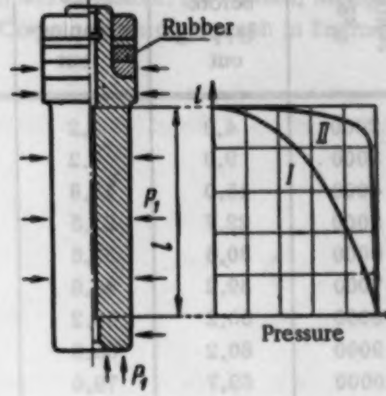

Fig. 2

Thus, it would appear that the third condition is ensured providing the pressure in the clearance is distributed normally, i.e. providing it falls smoothly from its measured value to zero. The latter condition is fully met only in cylinders without counter-pressure. In cylinders with counter-pressure this condition is fully met only with relatively small pressures. The reduction of the clearance in the upper part of the cylinder due to the external pressure on its walls at high pressures can become so large that it will lead to a virtually complete "disappearance" of the clearance. Local narrowing of the clearance will disturb the conditions for the movement of the liquid and lead to a sharp redistribution of pressure. There will appear sudden (almost discontinuous) variations in pressure at the upper end of the clearance (Fig. 2, curve II). The operating portion will then virtually be displaced upwards where there is a small pressure difference and the maximum speed in the movement of the liquid.

For the above operating conditions of piston systems with counter-pressure the application of the theory cannot be justified for the following reasons.

1. At the upper part of the clearance which now represents its main operating part there is a jump in pressure in whose vicinity the deformations depart considerably from those calculated by means of Lamé's equation [5].

2. It is no longer possible to neglect the effect of the upper "end" of the cylinder and its sealing, since their effect is now extended to the entire operating part of the clearance.

Thus, above a certain pressure the normal operating conditions of a system with counter-pressure are disturbed, producing considerable deviations of deformations from their theoretical values.

In order to verify the above assumption the counter-pressure cylinder bore was slightly lapped out in its upper part.

The position of the experimental curve showing the difference of deformation errors after lapping-out (Table 3, Fig. 3) changed considerably. For pressures of 10,000 kg-wt/cm^2 the measured error difference coincided with the theoretical difference, and for pressures of 6,000-9,000 kg-wt/cm^2 a discrepancy appeared in the opposite direction. Similar qualitative results were obtained in experiments with piston system No. IV (Table 3). The new error curves obtained after lapping-out of the cylinders represent essentially the previously-noted phenomena, but they are displaced towards higher pressures.

In fact, the position of the experimental curves obtained before lapping-out is higher than that of the theoretical ones in the range of 3000-4000 kg-wt/cm² and is due to the distortion of the original piston shape, thus producing an additional force which tends to increase the pressure. A rise in this force is prevented by an opposite phenomenon

TABLE 3

Nominal pressure, kg-wt/cm²	Difference in readings of the compared piston systems, kg-wt/cm²					
	8/3 − 1/6			IV/6 − 8/3		
	experimental		calculated values	experimental		calculated values
	before lapping-out	after lapping-out		before lapping-out	after lapping-out	
2000	4.3	3.2	3.2	2.9	–	3.1
3000	9.0	7.2	7.2	7.9	–	7.0
4000	15.0	13.8	17.2	13.7	–	12.4
5000	22.7	21.5	19.9	19.9	20.2	19.4
6000	30.6	32.6	28.7	27.9	30.4	27.9
7000	39.2	44.6	39.0	37.6	43.0	38.0
8000	50.2	56.2	50.9	47.2	54.9	49.7
9000	60.2	65.6	64.4	55.3	65.3	62.9
10000	69.7	79.0	79.6	60.8	77.2	77.6

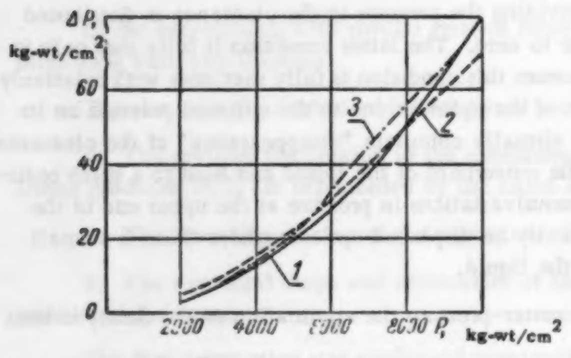

Fig. 3. Piston systems 1/6 − 8/3. 1) Calculated; 2) mean experimental before lapping-out; 3) mean experimental after lapping-out.

related to the "closing" of the clearance, which becomes effective in the selected piston systems at pressures of the order of 5000-6000 kg-wt/cm².

The position of the experimental data after lapping-out, which is above the theoretical ones in the range of 5,000-6,000 kg-wt/cm², is again due to the deformation of the piston shape. The previously-observed rise in the experimental curves now occurs at higher pressures, hence the value of the additional force on the cylinder also increases. The pressure at which the "closing" of the clearance becomes effective is now shifted to 8000-9000 kg-wt/cm². At higher pressures a downward placement of the experimental curve is to be expected.

The experiments confirm that the discrepancies of errors in comparing dissimilar piston systems occur in systems with counter-pressure and are due to the anomalies occurring when the clearance is "closed."

CONCLUSIONS

1. Experimental differences in errors of piston systems with normal cylinders coincide with those calculated from M. K. Zhokhovskii's formulas up to pressures of 10000 kg-wt/cm². The discrepancies between the experimental and calculated results do not exceed 0.05% at maximum pressure and are due to a distortion of the regular initial shape of the piston and probably of the cylinder bore.

2. For piston systems with counter-pressure and a range extending up to 10000 kg-wt/cm² whose pistons are fitted to the cylinders by means of the existing method, the propositions made in paragraph 1 will apply up to pressures of the order of 5000-6000 kg-wt/cm².

At higher pressures the effect of the "closing" of the clearance begins to disturb the normal operating conditions of piston systems and produces a discrepancy between the theoretical and experimental values of the corrections. The application of the calculated corrections in the above systems with the existing setting of the clearance becomes

permissible up to 10,000 kg-wt/cm^2 providing the clearance between the piston and cylinder is increased in the upper part of the cylinder.

3. For a better than a 0.05% agreement between the theoretical and experimental values of error deformations, additional investigation concerning the regular shape of the piston and cylinder bore is required.

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VIBRATION DYNAMOMETERS

L. G. Étkin

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This article deals with a new type of dynamometer instruments whose design is described. These instruments are called vibration dynamometers and are intended for high-precision measurements.

A vibration dynamometer (Fig. 1) consists of an elastic ring 1 which has a cross section of $d_1 \times h_1$ and a length of l_1 and is subjected to the measured load through a transverse tie plate 2 with a small cross section $d_2 \times h_2$ as compared with the ring, and of a stem 3 which also has a small cross section $d_3 \times h_3$. The ring, the tie plate and the stem are made from one piece of 35KhGSA steel, thus forming a single component. Exciters 5 and 7 and moving iron transducers 4 and 6 are mounted near the tie plate and the stem. The vibration dynamometer has two oscillating systems. The first consists of the transverse tie plate 2, transducer 4, exciter 5 and amplifier 8, and the second of stem 3, transducer 6, exciter 7 and amplifier 9.

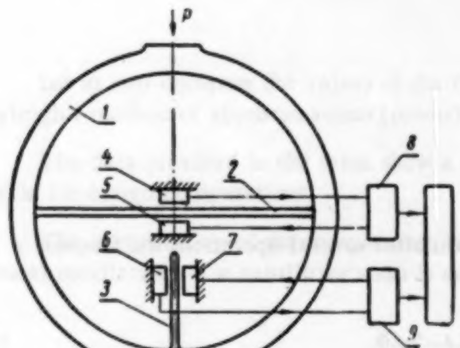

Fig. 1

Each of the above systems constitutes an electromechanical self-oscillating system of the type of a tuning fork oscillator. Let us take the first system as an example for describing its operation.

The oscillations of tie plate 2 induce in transducer 4 an emf, whose frequency is equal to that of the tie plate oscillations. From transducer 4 the signal is fed to the input of amplifier 8, whose output is connected to exciter 5. Thus the self-oscillatory system is closed. The oscillation frequency of such a system is virtually equal to that of the tie plate oscillations. This is due to the fact that the Q-factor of a mechanical oscillating system is very high (of the order of $5\text{-}10 \cdot 10^3$).

The second self-oscillatory system works in a similar manner.

When a compression load P is applied to the dynamometer the ring is deformed, tie plate 2 becomes extended, and the frequency of its oscillation rises. The difference between the natural oscillation frequency of an unloaded and of a loaded tie plate depends on the load applied to the dynamometer.

Stem 3 serves to apply temperature compensation to the dynamometer readings. The natural oscillation frequency of stem 3 does not change with loading of the dynamometer. It only varies with the variation of the dynamometer elasticity due to temperature.

The registration of the dynamometer readings amounts to measuring the oscillation frequency of transverse tie plate 2. In the simplest case it is possible to measure the number of oscillations of tie plate 2 during a time interval set by the oscillating frequency of stem 3.

Let us examine the design of vibration dynamometers from the example of a five-ton dynamometer.

The dimensions of the ring are selected on the basis of structural considerations and the required elasticity. Moreover, for the sake of simplicity the effect of the tie plate is neglected.

Force N, which arises in the tie plate when the ring is compressed, is determined from the condition of a simultaneous deformation of the ring and the tie plate

$$\Delta_h + \delta_N = \Delta_N, \tag{1}$$

where δ_N is the extension of the tie plate under the effect of force N; Δ_h is the increase in the horizontal diameter of the ring under the effect of force P; Δ_N is the reduction in the horizontal diameter of the ring under the effect of force N.

Hence

$$N = \frac{0.137\, PR^3}{I_1\left(0.149\, \frac{R^3}{I_1} + \frac{l}{F_2}\right)}. \tag{2}$$

The frequency of the horizontal tie plate transverse oscillations is determined, taking into consideration tensile force N from the equation of the tie plate's free oscillations:

$$\frac{EI_2}{m} \cdot \frac{\partial^4 y}{\partial x^4} + \frac{\partial^2 y}{\partial t^2} - \frac{N}{m} \cdot \frac{\partial^2 y}{\partial x^2} = 0. \tag{3}$$

Let us find the solution in the form

$$y = X(x)\, T(t).$$

Then (3) is separated into two equations

$$\frac{\ddot{T}}{T} = -p^2;$$

$$\frac{N}{m}\frac{X^{II}}{X} - \frac{EI_1}{m}\frac{X^{IV}}{X} = -p^2,$$

where p is the angular velocity of oscillations

By integrating this equation and using boundary conditions we obtain after several operations the frequency equation in the following form:

$$\frac{\alpha^2}{k^2} \sin S_1 l \cdot \operatorname{sh} S_2 l + 2 \operatorname{ch} S_2 l \cdot \cos S_1 l - 2 = 0, \tag{4}$$

where

$$\alpha = \sqrt[4]{\frac{N}{EI_2}};\quad k = \sqrt{\frac{mp^2}{EI_2}};$$

$$S_1 = \sqrt{\frac{\alpha^2}{2} + \sqrt{\frac{\alpha^4}{4} + k^4}};$$

$$S_2 = \sqrt{-\frac{\alpha^2}{2} + \sqrt{\frac{\alpha^4}{4} + k^4}}.$$

Equation (4) is transcendental and can only be solved by a method of approximations.

The tie plate's natural frequency of oscillations can be obtained by means of Rayleigh's approximations. Let us take for the equation of an elastic tie plate line that of an elastic beam line with fixed ends and a uniformly distributed load. The sagging deflection in this instance will have the form

$$y=\frac{qx^2}{24EI_2}\,(x^2-2l_1x+l_1^2).$$

The potential energy of the tie plate deflection is

$$V=\frac{EI_2}{2}\int_0^{l_1}\left(\frac{d^2y}{dx^2}\right)^2 dx=\frac{0.8q^2l_1^5}{1152EI_2}.$$

Let us assume that the deflection of the tie plate varies under the effect of its oscillations according to a harmonic law. The maximum kinetic energy in the tie plate oscillations is determined by the expression

$$T=\frac{qp^2}{2g}\int_0^{l_1}y^2dx=\frac{q^3p^2l^9}{1152gE^2I_2^2\cdot 630}.$$

The work done by tensile force N in bending the tie plate is

$$A=\frac{N}{2}\int_0^{l_1}\left(\frac{dy}{dx}\right)^2 dx=\frac{2Nq^2l^7}{1152E^2I_2^2\cdot 105}.$$

The frequency of free oscillations is

$$T = V + A .$$

The frequency of the tie plate's free oscillations is determined by the expression

$$p=\frac{1}{l^4}\sqrt{\frac{g\,(504EI_2+12Nl_1^2)}{q}}. \tag{5}$$

Let us now compare the values of the tie plate's free oscillations in a vibration dynamometer obtained by Rayleigh's method of approximations (power) and by means of a numerical solution (4).

The data provided in the table show a good agreement between the two methods. The accuracy thus obtained is ample for design computations.

The computation of the temperature compensation stem does not present any difficulties. The frequency of natural oscillations of a cantilever stem is determined from the known expression

$$p=\frac{\alpha^2}{2\pi l_2^2}\sqrt{\frac{EI_1}{\gamma F}\,g}, \tag{6}$$

where γ is the specific gravity of the elastic element; F is the cross sectional area; g is the acceleration due to gravity; α is the root of the frequency equation which is equal, for the first type of oscillations, to 1.875;

In our case (6) can be simplified to

$$p=8.12\cdot 10^5\,\frac{h^3}{l_2^2}. \tag{7}$$

Formula (7) is derived for $E = 2 \cdot 10^4$ kg-wt/mm², $\gamma = 7.8 \cdot 10^{-6}$ kg/mm³, and $g = 9.8 \cdot 10^3$ mm/sec².

The frequency p_n of free transverse oscillations of the temperature compensation stem is selected so as to obtain the best compensation at the required load. Thus, if the best compensation is required at zero load, frequency p_n is made equal to that of the free transverse oscillations of the horizontal tie plate at zero load on the dynamometer. If the best temperature compensation is required at a given load on the dynamometer, frequency p_n is made equal to that of the transverse oscillations of the horizontal tie plate at that load of the dynamometer.

Load on the dynamometer, kg-wt	Angular frequency obtained by		Error, % $\frac{f_2 - f_1}{f_2} \cdot 100$
	Rayleigh's method f_1	the numerical method f_2	
0	21965	21904	-0.30
1000	21370	21282	-0.41
2000	20775	20700	-0.36
3000	20154	20180	+0.13
4000	19513	19670	+0.80

Fig. 2 shows the relation between the free transverse oscillations frequency of the horizontal tie plate and the load P for various thicknesses h of the tie plate, and Fig. 3 shows a similar relation for various lengths l of the tie plate. Both graphs have been plotted for a five-ton dynamometer. From these graphs it will be seen that as the tie plate becomes thinner, the sensitivity of the galvanometer rises. However, the nonlinearity of the dynamometer characteristic rises with its sensitivity.

In designing vibration dynamometers it is necessary to remove the junctions of the tie plate with the dynamometer from its bearing surfaces, in order to prevent the conditions of fixing the dynamometer from affecting the vibration frequency and Q-factor of the tie plate. The cantilever bracket for mounting the exciters and transducer should be fixed in such a manner that the air gaps between the transducers, exciters and the corresponding tie plates do not change when the dynamometer is loaded.

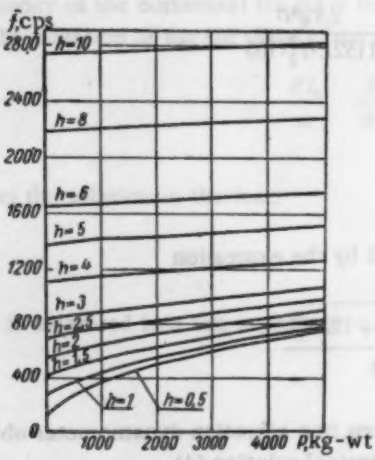

Fig. 2

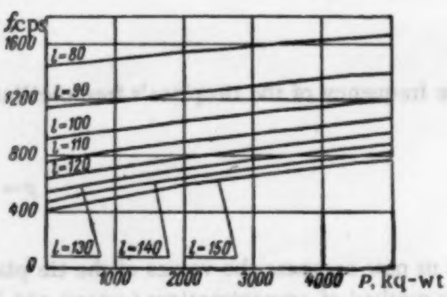

Fig. 3

A good temperature compensation of vibration dynamometers can only be attained if the temperature of the elastic body and the tie plates is the same. Hence, it is necessary to place the vibration dynamometer in a hermetically sealed jacket in order to equalize the temperature of the elastic body and the tie plates.

The basic errors of vibration dynamometers are produced by variations in the temperature of the elastic body, the effect of electromagnetic induction on the stability of the frequency of the tie plate transverse free oscillations, and the effect of the variable longitudinal force, which arises in the tie plate during its transverse oscillations, on the frequency of its free transverse oscillations.

When the temperature of the dynamometer's elastic body varies by ΔT, the dynamometer linear dimensions change, if we take the first approximation, according to a linear law

$$L_t = L\,(1 + \alpha\Delta T),$$

where α is the coefficient of linear expansion.

The density of the elastic element changes in the following manner:

$$V_t=\gamma(1+\alpha\Delta T)^{-3}.$$

The modulus of elasticity of the elastic element also changes with temperature. In the temperature range of 0 to 100°C the modulus of elasticity varies linearly:

$$E_t=E(1-\beta\Delta T),$$

where β is the temperature coefficient of the modulus of elasticity.

The frequence of the tie plate transverse free oscillations is determined for a temperature rise of ΔT in the following manner:

$$p_t=\frac{1}{l^2}\sqrt{\frac{12g}{\gamma bh}\left[3.5Ebh^3(1-\beta\Delta T)(1+\alpha\Delta T)+Nl^2(1+\alpha\Delta T)^{-1}\right]}. \tag{8}$$

The relative variation of frequency can be represented in the form

$$\varepsilon_{pt}=\frac{p_t-p}{p}.$$

If we assume that

$$(1-\beta\Delta T)(1+\alpha\Delta T)=1-(\beta-\alpha)\Delta T$$
$$(1+\alpha\Delta T)^{-1}\approx 1-\alpha\Delta T,$$

then

$$\varepsilon_{pt}=\sqrt{1-\frac{\beta+\left(0.286\,\frac{Nl^2}{Ebh^3}-1\right)\alpha}{1+0.286\,\frac{Nl^2}{Ebh^3}}\Delta T}-1. \tag{9}$$

Fig. 4 shows temperature error graphs for a temperature compensated at a zero load.

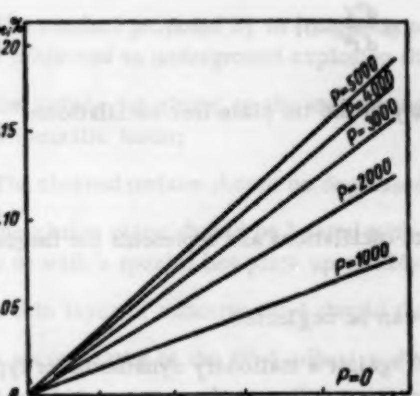

Fig. 4

Let us now evaluate the effect of the moving-iron exciter on the stability of the frequency of the horizontal tie plate oscillations.

The elastic oscillatory system driven by the moving-iron exciter is, as we know, a nonlinear oscillating system [1]. In any system of that type the amplitude and frequency of oscillations bear a definite relation to each other. The elastic oscillating system driven by the moving iron exciter is a soft oscillatory system, i.e. a system in which a rising amplitude of free oscillations reduces the frequency.

Let us examine free oscillations of an elastic oscillatory system without dissipating forces but with a constant magnetization of the moving-iron exciter.

In the first approximation the equation for free oscillations can be written in the following form:

$$m\ddot{x}+c_1x-c_3x^3=0. \tag{10}$$

In solving this equation by Duffing's method [2] we obtain the following relation between the free oscillations frequency and amplitude;

$$\omega^2 = \frac{c_1}{m} - \frac{3}{4}\frac{c_2}{m}x^2. \tag{11}$$

At present the tie plate and stem are driven by moving-iron exciters type VTM-Kristall which are used in hearing-aids. Moreover, the excitation systems are provided with stabilization of the oscillation amplitude. In the vibration dynamometers under consideration the effect of the moving-iron exciter on the frequency of the tie plate and stem oscillations can, therefore, be neglected. This is justified by numerous experiments.

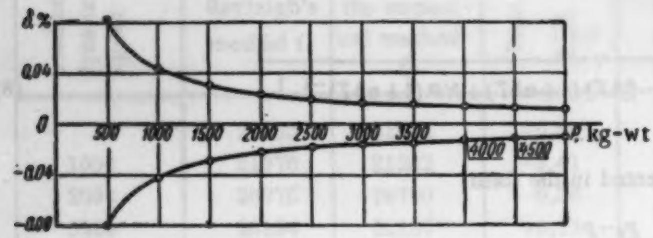

Fig. 5

The transverse oscillations of the horizontal tie plate with fixed ends, produce longitudinal forces which affect the frequency of the free oscillations. Let us evaluate these forces considering that the junction of the tie plate with the ring is not rigid, but elastic.

The free oscillations of the tie plate under the effect of a variable longitudinal force $S(t)$ is represented by the following differential equation [3]:

$$EI_1 \frac{d^4y}{dx^4} + m\frac{d^2y}{dt^2} - S(t)\frac{d^2y}{dx^2} = 0. \tag{12}$$

Let us express the variable force $S(t)$ in terms of stiffness and elongation of the tie plate;

$$\Delta l = \int_0^l (dS - dx) = \frac{1}{2}\int_0^l y'^2\, dx.$$

The longitudinal stiffness of the tie plate is $c_1 = EF_1/l$.

The stiffness of the ring $c_2 = EI_2/0.149R^3$.

Equation (12) assumes the form

$$EI_1 \frac{d^4y}{dx^4} - \left(\frac{1}{2}\frac{c_1 c_2}{c_1+c_2}\int_0^l y'^2\, dx\right)\frac{d^2y}{dx^2} + m\frac{d^2y}{dt^2} = 0. \tag{13}$$

The solution of (13) gives the following expression for the frequency of the tie plate free oscillations:

$$f = f_0\chi,$$

where χ is the variable which depends on the amplitude of the tie plate oscillations and represents the frequency error introduced by the variable longitudinal force $S(t)$.

In stabilizing the amplitude of the tie plate oscillations this error can be neglected.

The accuracy of the 5 ton-wt vibration dynamometer was checked against a stationary dynamometer type DO-II-5 with a range of 5 ton-wt. The error of the reference dynamometer according to the tests carried out by the VNIIM amounts to 0.1% of the measured load.

On the basis of 10 measurements a graph of the variations in the vibration dynamometer readings was plotted (Fig. 5). The preliminary testing of the 5 ton-wt vibration dynamometer indicates the possibility of producing vibration dynamometers with measurement errors of the order of 0.1%.

An obvious advantage of vibration dynamometers is the possibility of producing registering equipment with an error several orders lower than that of the elastic element.

The defect of vibration dynamometers consists of their nonlinear characteristic. At present, work is being conducted for producing vibration dynamometers with a linear characteristic.

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METHOD FOR GLUING AND SEALING STRAIN-GAUGE TRANSDUCERS

N. G. Mikhailovskii

Translated from Izmeritel'naya Tekhnika, No. 12,
p. 31, December, 1961

In experimental work involving the use of strain-gauge measurements a considerable time is spent on gluing, drying and hermetically sealing the strain gauges, especially if the latter are in contact with corrosive media (seawater) and are affected mechanically by underground explosion shock waves.

Experience has shown that hermetic sealing by the "cocoon" method is unsuitable for these conditions. Under the effect of shock waves the "cocoon" is deformed, impinges on the strain gauge, breaks it and tears off the wires at their soldered joints.

Hermetic sealing of strain gauges by gluing over them rubber-impregnated fabrics can only be used when it is possible to take the lead-out wires into the body of the device (a separate hermetically-sealed compartment). Moreover, the structure of the device is considerably weakened by being drilled, even at a large distance from the place where the strain gauges are glued on. For small components (hooks, grabs, drawbars, struts, etc.), which have small areas for gluing on the strain gauges, this method cannot be applied at all.

Both methods are very labor-consuming and impede a rapid changing of damaged strain gauges.

The method proposed by us for gluing on and hermetically-sealing strain gauges which are used in corrosive media and are subjected to underground explosion shock waves includes the following operations:

the surface for gluing on the strain gauge must be cleaned and any paint or rust removed from it, so that it acquires a metallic luster;

The cleaned surface should be degreased with benzine, white spirit, or any other grease solvent;

the gluing place should be heated with a drying lamp (a reflector with a special helical winding on a porcelain former) or with a special hot plate up to 110-120°C;

a thin layer of adhesive BF-4 should then be applied to the gluing place and dried;

a second layer of the BF-4 adhesive should then be applied and dried;

the strain gauges are then glued;

the conductors soldered on;

a layer of a mixture is then applied, which is heated up to 100°C and consists of 40% of ZZK-2 (ZZK-3) cement, 30% of rosin and 30% of beeswax;

and finally a second layer of the ZZK-2 mixture of rosin and wax is applied.

The heated mixture should be applied to a preheated strain gauge as well as around it with an ordinary brush used for office glue. It is necessary to cover the connecting leads and soldered joints carefully with the mixture.

If, in the course of these operations the upper layer of the mixture is damaged (accidental scratches due to contact with external objects), it is necessary to use PVE-6 enamel, which should be applied to the preheated strain gauge and the place to which it has to be glued, in two layers, as well as to the conductors before they are covered with the ZZK-2 mixture of wax and resin.

Experience has shown that the insulation resistance between the strain-gauge wires and the metallic surface to which it was glued did not vary and amounted to 100 meg after two months operation in seawater.

CONCLUSIONS

The above method of gluing and hermetically-sealing strain gauges ensured successful experiments in corrosive media under the effects of underwater explosion shock waves and preserves the strain gauges from damage for a long time.

Tests have shown that the use of drying lamps or special hot plates reduces the gluing and drying time as compared with other methods of drying strain gauges.

CHECKING TAXIMETERS

(Comments on A. I. Suvorov's article)*

Translated from Izmeritel'naya Tekhnika, No. 12
pp. 31-33, December, 1961

Taxi transport has rapidly increased in our country in recent years. The taxis are fitted with meters which are checked by State Inspection Laboratories for measuring equipment.

A. I. Suvorov's article on "Checking taximeters" has provoked a number of comments from industrial and state inspection laboratory workers.

É. V. Kolodeichik, taxi-driver of the Ordzhonikidze taxi depot considers that the problem raised by A. I. Suvorov is correct and timely. Existing methods of checking taximeters, states É. V. Kolodeichik, lead to unnecessary expenditure of state funds, since the checking of meters does not improve their quality after they have been repaired, but only delays their delivery and keeps the taxis out of service. É. V. Kolodeichik suggests that state testing of taximeters should be abolished and the garage foreman entrusted with the testing.

The workers of the Ivanovo taxi depot, at their general meeting, discussed A. I. Suvorov's article and completely agreed with his opinion. They state: "State testing of taximeters does not produce the results we require. After state testing the meters often work incorrectly." The main reason for the low quality of the state testing of meters is that they are only checked over a small measuring range. The most rational method of checking the quality of taximeters after repair should provide for the running of the meter at a high speed of the driving axle over the whole measuring range, thus raising considerably the reliability of its operation. The workers at the Ivanovo taxi depot express their desire to see the new methods for testing taximeters applied as soon as possible.

K. S. Bashmakov, chief engineer of the VNIIM (All-Union Scientific Research Institute of Metrology) test laboratory, writes that the taximeter serves a double purpose, for settling the passenger's account with the chauffeur, and for the chauffeur's account with the taxi depot. Such a settlement of accounts requires a more careful approach to the checking of taximeter readings and, hence, the state testing of meters by the Committee's agencies must be retained.

*Izmeritel'naya tekhnika, 1961, No. 5.

K. S. Bashmakov does not agree with A. I. Suvorov that the basic measuring unit of a taximeter consists of the clockwork mechanism. He considers that the basic unit consists of the face meter and the "till" meter, since all the accounts are settled according to their readings.

The readings of the total distance, paid journey, control distance and number of fares meters are not, as a rule, used for settling accounts; they partly fulfill control functions and are mainly used for recording the perfomance of taxis in service. According to their readings the intensity of taxi service is analyzed and their operating graphs established.

Indexes	Operating instruction		Manufacturing plant specification	
	TA-49A	TA-49B	TA-49A1	TA-49B1
Permissible difference between the readings of the total distance meter and the calculated value of any journey travelled by the taxis, km.	±0.1	±0.1	±0.1	±0.1
Permissible difference between the meter reading of a paid journey and the reading of the total distance meter, km.	±0.2	±0.2	±0.1	±0.1
Permissible difference between the face meter reading and the calculated value of the journey, kopeks.	±10	±10	±3	±3
Permissible discrepancy between the face and the "till" meter readings, kopeks.	–	–	±1	±1
Duration of the clockwork mechanism operation, hours.	8	8	6	4
Permissible error in the clockwork mechanism, minutes.	±4	±4	Not stated	

K. S. Bashmakov states that in service the taximeter operates only a short time from the clockwork mechanism, amounting approximately to 6 to 10% of the total.

K. S. Bashmakov agrees with A. I. Suvorov that the existing operating instructions have become obsolete and do not satisfy inspection workers.

The existing operating instructions provide for the testing of only two types of taximeters, TA-49A and TA-49B, and do not provide for the testing of several other types, such as TA-49A1 and TA-49B1, which are different in design from the first two types.

There are contradictions, shown in the attached table, between the requirements and methods provided in the technical specifications and those described in the operating instructions.

K. S. Bashmakov does not consider it necessary to check the taximeters over the whole of their range, since in the main only two of the meter drums operate intensely. This fact has been confirmed by the study of the operation of taxi meters in Leningrad. He also considers that a speedy method of checking taximeters as suggested by A. I. Suvorov is contrary to the normal operation of the instrument and will lead to premature wear of the reduction gear components. A speed of 12 km/hr for testing taximeters is sufficiently high.

In conclusion K. S. Bashmakov draws attention especially to the necessity of providing state inspection laboratories with standard equipment (racks), since at present the Committee's laboratories are making test racks by their own efforts, which leads to an unproductive expenditure of time and state funds.

A. I. Suvorov, in addition to the suggestions made in his article, considers that in revising the existing instruction it is necessary to include in it the checking of the customer's meter by means of appropriate equipment, as well as methods for checking the reliable and accurate operation of the control distance meter.

Editorial note. The problem of the methods for testing taximeters raised by A. I. Suvorov is topical. Unfortunately, the existing operating instructions on checking taximeters do not ensure their stable and reliable operation under service conditions. The instruction must be altered, taking into consideration forced operating conditions for checking the meters for wear.

The comrades who suggest the abolition of state testing of taximeters are wrong. It should be preserved, but new testing methods should be developed and appropriate testing equipment produced. The measuring instrument administrations of the Committee, in conjunction with the VNIIK, should revise as speedily as possible the existing operating instructions and include in them a description of test methods which would ensure a stable and reliable operation of the meters under service conditions.

COMPUTATION OF THE BASIC PARAMETERS FOR A TELESCOPE OF A RADIATION PYROMETER WITH A THERMISTOR

Vanbo Pak

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 33-35, December, 1961

Telescopes for radiation pyrometers with thermopile sensing elements consisting of metal thermocouples are now being used widely in industry.

They have as yet an insufficiently high stability; in particular the readings of their telescopes whose receivers consist of thermopiles are greatly influenced by geometrical factors (dimensions of the radiator, distance of the telescope from the object).

One method for reducing this effect consists of replacing the thermopile by a thermistor. In the latter case it is unnecessary to solve the constructional problem about the mutual location of hot and cold junctions.

Owing to a number of considerations it is preferable to use thermistors as receivers in telescopes in place of metal thermocouples, despite the advantage of the latter consisting of their linear relation to temperature.

It should be noted that the reproducibility of telescope readings can be improved if in the general heat-exchange balance between the thermal element and the surrounding medium, preference is given to a more stable component, namely, to heat conduction instead of convection. In practice this can be attained if the heat loss of the thermal element through its lead-out conductors is raised, but this in turn reduces sensitivity. Hence, this problem can only be solved by using a more sensitive element, for instance, a thermistor.

In developing such a radiation pyrometer it is most important to evaluate in advance the element's mean bulk temperature which corresponds to the upper temperature measuring limit, to derive and analyze the telescope sensitivity equation, and to evaluate thermal inertia. Below we examine these problems for an element consisting of a thermistor, for instance, of type TSH-1.

Computation of the pyrometer thermoelement temperature. In order to evaluate the temperature of a thermistor which serves as a thermal receiver for a radiation pyrometer, let us derive a power-balance equation for the thermal receiver which is being exposed to heat and is connected to a measuring circuit.

The heat effect produced by the current flowing through the thermal element and the radiation energy absorbed by it and equal in brightness to the measured grey-body source, multiplied by a certain constant of the telescope

$$K=k_1k_2\frac{s\cdot s_1}{d^2}, \tag{1}$$

will heat up the element and produce a temperature difference between the element and the surrounding medium.

The power balance equation can be written as

$$\begin{aligned} &i^2R+k_1k_2\frac{\sigma}{\pi}\;T_p^4\frac{s_1s_2}{d^2}\\ &=H\frac{du}{d\tau}+\alpha\,(u-\theta)+2\lambda\,\frac{p}{l}\,(u-\theta), \end{aligned} \tag{2}$$

where $\underline{i}$ is the current flowing through the thermal element; R is the resistance of the element; k_1 is the element's total absorption factor which depends on the physical properties and the surface condition of the element; k_2 is the transmission factor of the optical system in the refractor-type telescope; σ is a constant equal to $5.673\cdot10^{-12}\,\mathrm{w\cdot cm^{-2}\cdot deg^{-4}}$; T_p is the absolute temperature of the radiating object; s_1 is the effective area of the objective; s_2 is the area of the receiving element projection onto a plane perpendicular to the sighting line; $\underline{d}$ is the distance from the object to the receiver; H is the thermal capacity of the sensing element; α is the heat transfer coefficient equal to the sum

of the convection and radiation coefficients $\alpha_c + \alpha_r = \alpha$; ϑ is the temperature of the surrounding medium; u is the mean bulk temperature of the thermal element; λ is the heat conduction factor of the thermal element lead-in conductors; l is the length of the lead-in conductors; p is the cross sectional area of a conductor.

Equation (2) holds for any instant of the transient process.

For condition

$$\frac{du}{d\tau}=0, \tag{3}$$

equation (2) can be rewritten as

$$i^2R+k_1k_2\sigma\, T_p^4\,\frac{s_1s_2}{\pi d^2}=\alpha\,(u-\vartheta)+2\lambda\,\frac{(u-\vartheta)}{l}\cdot p. \tag{4}$$

Equation (3) means physically that the power fed to the thermal element is dissipated on maintaining a certain constant temperature difference $u-\vartheta$. This difference is obtained from (4):

$$u-\vartheta=\frac{i^2R+k_1k_2\sigma\, T_p^4\,\frac{s_1s_2}{\pi d^2}}{\alpha+2\lambda\,\frac{p}{l}}. \tag{5}$$

A numerical example. Let us assume that:

1) The temperature of the object (the black-body coefficient approaching unity) $T_p = 2000°K$;

2) the experimentally-obtained value of the total heat transfer factor B of a type TSh-1 thermistor inside a chamber at $\vartheta = 20°C$ is

$$B=\alpha+2\lambda\,\frac{p}{l}\approx 0.11\ \text{mw / deg};$$

3) the current flowing through the thermistor is $i = 0.3 \cdot 10^{-3}$ amp;

4) the resistance of the element is $R \approx 200$ ohm;

5) the total absorption coefficient for a black-body thermal element is $k_1 \approx 0.8$;

6) the transmission factor of a single lens glass objective is $k_2 \approx 0.8$;

7) the radiation constant is

$$\sigma = 5.673 \cdot 10^{-12}\ \text{w} \cdot \text{cm}^{-2} \cdot \text{deg}^{-4};$$

8) the distance between the objective and the thermal element is $d = 7.5$ cm;

9) the area of the thermal element's projection onto a plane perpendicular to the sighting line is, for a type TSh-1 thermistor 1.5 mm long and 0.15 mm in diameter, equal to $s_1 = 0.15 \cdot 0.015 \approx 0.225 \cdot 10^{-2} \cdot \text{cm}^2$;

10) for a diameter of $D = 3.8$ cm the effective area of the objective is

$$s_2=\frac{\pi D^2}{4}=11.3\ \text{cm}^2\,.$$

By substituting these values in (5) we find the excess temperature of the receiving element above the ambient temperature equal to 76°C. Hence, for a temperature of the object $T_p = 2000°K$ and an ambient temperature of $\vartheta = 20°C$ the receiving thermistor will have a mean bulk temperature of the order of 96°C.

Calculation of the radiation pyrometer telescope sensitivity. It will be seen from (5) that providing the conditions

$$\frac{dl}{d\tau}=0, \quad \frac{d\vartheta}{d\tau}=0, \quad \alpha=\text{const} \tag{6}$$

are met, the temperature of the thermal element will only be affected by the radiating object temperature T_p:

$$u=f(T_p). \tag{7}$$

The temperature of the thermal element with other conditions remaining constant will also depend on the configuration of the sensing element. Since the electrical resistance of the thermal element under condition (6) is determined by the value of its temperature u where

$$R=\varphi(u), \tag{8}$$

the sensitivity of the telescope whose transducer consists of a thermistor is determined by the expression

$$\delta=\frac{dR}{dT_p}=f'(T_p)\cdot\varphi'(u). \tag{9}$$

Graphically it represents the slope of the static characteristic curve of the relation between the thermal element resistance and the temperature of the measured object.

In order to find sensitivity δ it is necessary to determine the derivatives of (7) and (8).

From (5) the derivative u' will be

$$u'=f'(T_p)=\frac{4\sigma s_1 s_2 k_1 k_2}{\pi d^2\left(\alpha+2\lambda\,\frac{p}{l}\right)}\cdot T_p^3. \tag{10}$$

Function (8), which represents the relation between the resistance and temperature, is exponential and has the form of [1]

$$R_\tau=a\,e^{\frac{b}{T}}, \tag{11}$$

where R_T is the resistance of the semiconductor transducer (thermistor); a and b are parameters; T is the absolute temperature of the thermistor; e is the base of natural logarithms.

The derivative of (11) is

$$R'=\varphi'(u)=-\frac{b}{T^2}R_\tau=a_\tau\cdot R_\tau, \tag{12}$$

where α_T is the temperature coefficient of the thermistor.

By inserting the value of the derivatives thus obtained into (8), we have

$$\delta=\frac{4\sigma s_1 s_2 k_1 k_2 a_\tau\cdot R_\tau}{\pi d^2\left(\alpha+2\lambda\,\frac{p}{l}\right)}\cdot T_p^3. \tag{13}$$

The sensitivity of a radiation pyrometer will be determined, however, by the minimum variation in the radiated temperature which can be registered on the output measuring instrument.

Thermal inertia of a radiation pyrometer, is determined by the inertia of the telescope, providing the output measuring instrument is known to have a smaller inertia than the telescope. In turn the thermal inertia of the telescope depends on that of the heat-sensitive transducer. With a suitable design it is possible to attain small inertia in certain components, for instance, in the irising device. For this purpose the diaphragm must be bulky and have good

thermal contact with the body of the telescope. Then in the first approximation it will be possible to assume that the radiation pyrometer telescope inertia is equal to that of the semiconductor thermal element.

In order to determine the characteristic speed of the normal temperature restoration after the exposure let us examine the cooling process for a constant ambient temperature ϑ and a constant heat exchange factor.

If the thermal element of a radiation pyrometer cools from u_1 to $\underline{u}$ $(u_1 > u > \vartheta)$, the heat exchange differential equation between the thermal element and the surrounding medium will assume the form

$$Hdu+B(u-\vartheta)\,dt=0. \tag{14}$$

By solving this linear equation we obtain

$$\frac{u-\vartheta}{u_0-\vartheta}=e^{-\frac{t}{\tau_0}}. \tag{15}$$

The ration $H/B = \tau_0$ is known as the time constant [2].

The speed of reaction to a heat exposure is an important characteristic in radiation pyrometry. The temperature rise curve of the thermal element from the beginning of its exposure will be determined by the equation

$$\frac{u_0-\vartheta}{u_0-u}=e^{-\frac{t}{\tau_0}}, \tag{16}$$

where u_0 is the temperature to which the sensing element approaches asymptotically.

According to GOST (All-Union State Standard) 6923-54 the thermal inertia of a radiation pyrometer telescope is determined as the time interval between the commencement of heat exposure of the telescope which is at a temperature of 20 ± 2°C to the instant when the pyrometer attains 99% of its final stable-state reading.

From (16), the thermal inertia of the telescope is

$$t\approx\tau_0 \ln\frac{u_0-\vartheta}{0.01\cdot u_0}. \tag{17}$$

Example. If we take for a thermal element a measuring thermistor type TSh-1, then assuming that $\tau_0 = 0.8$ sec, $\vartheta = 20°C$, $u_0 = 96°C$, which corresponds to the temperature of the measured object of $T_p = 2000°K$, we shall find from (17) the value of thermal inertia to be equal to $t \approx 3.5$ sec.

CONCLUSIONS

Laboratory tests of an experimental model pyrometer using a thermistor type TSh-1 agree well with the calculated values. The above technique of preliminary calculation of the telescope's basic characteristics can be recommended for designing radiation pyrometers with different thermistors.

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THERMAL INERTIA OF THERMOCOUPLES

Yu. A. Zholkov

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When thermocouple readings are taken in static measurements it is sufficient to ascertain that the reading has attained a stable-state condition after any changes in the measured variable. This, however, is not sufficient in dynamic measurements, owing to the inertia of thermocouples.

Below we provide the results obtained in determining the inertia of chromel-alumel thermocouples of two designs, one with and the other without a jacket. The thermocouple without a jacket consisted of two 0.5 mm conductors, each braided with an asbestos thread. The other design consisted of a thermocouple without a jacket inserted in a 14 × 1 mm stainless steel tube. The hot junction was taken through a hole drilled in the ferrule and was silver-soldered. The tests* were carried out according to the method of a regular thermal condition [1, 2, 3].

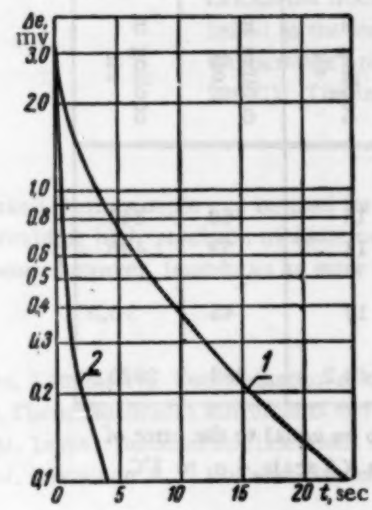

Fig. 1. Relation of the difference between the thermocouple hot junction temperature and the ambient temperature to the cooling time of a thermocouple without a jacket (the differerence of emfs is plotted along the Y axis). 1) Cooling in air; 2) cooling in oil.

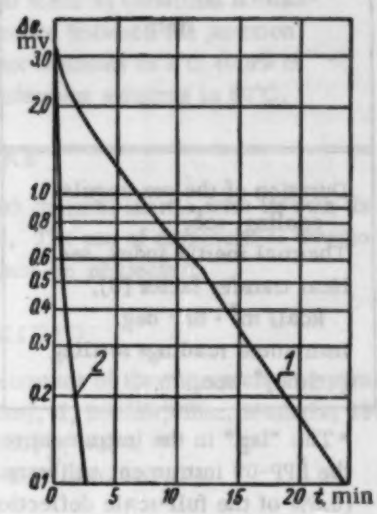

Fig. 2. Relation of the difference between the thermocouple hot junction temperature and the ambient temperature to the cooling time of a thermocouple in a jacket (the difference of emfs is plotted along the Y axis). 1) Cooling in air; 2) cooling in oil.

Figs. 1 and 2 show the relation between the thermocouple junction temperature and the cooling time. The curves have two sections; the first one is curved corresponding to the pre-regular condition of cooling; the second is straight, corresponding to the regular condition.

From the linear section of the curve it is possible to determine the thermocouple thermal inertia index:

$$\varepsilon = \frac{\tau'' - \tau'}{\ln\vartheta' - \ln\vartheta''} \text{ sec}, \tag{1}$$

* The experiments were conducted under the guidance of Yu. G. Mikhalenko; the processing of the experimental data and computations were made by G. P. Koroleva.

where (') denotes initial values and ("), values at the end of the linear section, both for time τ and also for the logarithm of the temperature difference, $\ln\vartheta = \ln(t-u)$, of the junction temperature t and the ambient temperature u.

From the above data it is possible to determine the time interval τ_y, between the instant at which the instrument attains stable-state readings and the instant [3] at which a regular thermal condition is reached:

$$\tau_y = \varepsilon \ln \frac{(t-u)_0}{\Delta t}, \qquad (2)$$

where t-u is the temperature difference between the thermocouple and the medium at the instant the regular thermal condition is attained, °C; Δt is the "lag" in the instrument reading, °C, which can also determine the permissible error of measurements.

Item	Notation	Thermocouple without a jacket (naked junction)		Thermocouple with a jacket	
		cooling in oil	cooling in air	cooling in oil	cooling in air
Duration of the pre-regular cooling, sec.		1.5	15	60	840
Thermal inertia index, sec.	ε	2.5	11	79	406
Heat transfer factor [3], kcal/ m² · hr · deg.	α	55	10	45	5.5
Instrument readings settling time,* sec.	τ_y	10	43.2	368	2020

* The "lag" in the instrument readings is assumed to be equal to the error of the ÉPP-09 instrument calibrated up to 200°C by the XA scale, i.e. to 1°C (0.5% of the full-scale deflection).

Thus, the total time which elapses before the instrument indicates the required temperature with a given accuracy is represented by the sum of the pre-regular period duration and the instrument settling time τ_y. This time interval will constitute the dynamic lagging of the instrument readings.

As a rough approximation we can consider [1] that the relation between the thermal inertia index ε and the heat-transfer factor α has the shape of a hyperbola (a characteristic curve for the thermal inertia of a thermocouple). Then it becomes possible to construct from the above data* characteristic curves for the thermocouple both in a jacket and with a bare junction. The table provides the data thus obtained, and Fig. 3 the characteristic curves.

These data have been obtained for atmospheric pressure, a temperature of 100°C and room temperature for cooling. It will be seen from the above data that for a thermocouple with a naked junction and $\alpha = 55$ kcal / m² · hr · deg and an initial difference in temperature between the measured medium and the junction of 80°C, the dynamic lag in the instrument readings amounts to 1.5 sec + 10 sec = 11.5 sec, and for an $\alpha = 10$ kcal/ m² · hr · deg these values are respectively 15 sec + 43.2 sec = 58.2 sec. Testing has shown [3] that for the same value of α at higher temperatures the thermal inertia for the majority of thermocouples is considerably smaller. Moreover, high speeds of gas movement and an increased pressure raise the value of α, thus lowering still further the thermal inertia index.

* The hyperbola becomes equilateral for $\alpha_1 \varepsilon_1 = \alpha_2 \varepsilon_2$. In a general case this condition is not met, but the displacement of the hyperbola's asymptote with respect to the Y axis can be determined from the formula $a = (\alpha_1\varepsilon_1 - \alpha_2\varepsilon_2)/\alpha_1 - \alpha_2)$.

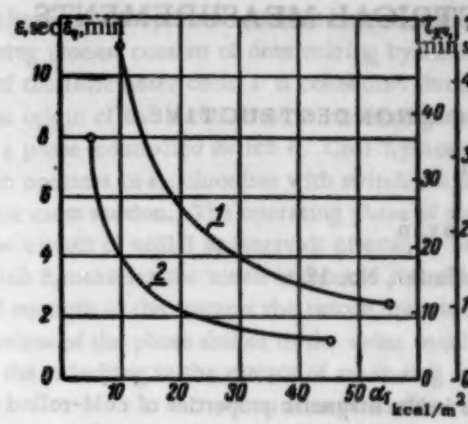

Fig. 3. Tentative characteristic curves of the thermal inertia of thermocouples. 1) Without a jacket (a naked junction); 2) with a jacket; τ_y is the settling time of instrument readings calculated from the instant a regular thermal condition is established to the instant when the difference between the junction temperature and the real temperature amounts to 1°C (0.5% of 200°C). The initial temperature difference amounts to 80°C.

CONCLUSIONS

A naked thermocouple can be used for studying objects with thermal inertia, with its own thermal inertia neglected, providing high-precision measurements are not required. The use of commercial thermocouples for dynamic measurements, however, introduces an error which normally cannot be neglected.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

ELECTRICAL MEASUREMENTS

TECHNIQUE AND EQUIPMENT FOR NONDESTRUCTIVE TESTING OF ELECTRICAL STEEL

R. I. Yanus and Yu. A. Vdovin

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Owing to the considerable difference in the magnetic properties of cold-rolled steel sheets [1], the only way of raising the accuracy in evaluating the mean properties of a tested batch of sheets consists of substituting sample testing by testing all the sheets without exception [2]. The requirements for such checking amount, in the main, to the following: It must not damage the material, it should have a high productive capacity with adequate accuracy of measurement, and provide facilities for making the sorting of sheets automatic. The metal should be tested in the shapes (sheets or rollers) specified by the GOST (All-Union State Standard). In order to raise the productive capacity of this method it is advisable not to check all the characteristics (very numerous) specified by the GOST, but to select one or two of the most important characteristics, since otherwise the productive capacity will suffer and the checking procedure will be made considerably more complicated.

Analysis of the results of five years' shop testing of cold-rolled electrical steel at a metal plant has shown [3] that for the grain-orientated cold-rolled electrical steel, characteristic B_{25} constitutes the most sensitive indication

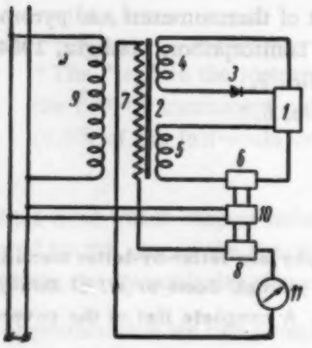

Fig. 1

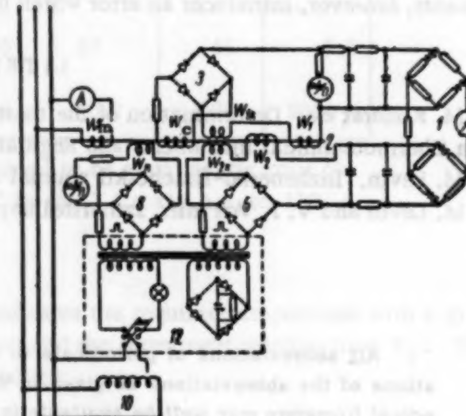

Fig. 2

of its quality, and if the metal meets the GOST in parameter B_{25} it will be satisfactory for all the remaining parameters. It is therefore possible to limit mass testing of cold-rolled steel with respect to the value of B_{25} alone.

The drawback of known methods in determining induction consists in the need to determine in advance the cross sectional area of the measured object.

We are suggesting a method of measuring induction by an alternating current in sheets or rollers [4], which does not require determination of the cross sectional area.

It consists of measuring the ratio of the flux in the sample at a given field strength to the saturation flux in the same sample, and calculating, from this ratio and the known saturation flux for the given brand of steel, the actual induction in the sample.

Fig. 1 shows the block schematic of a device for measuring induction. The magnetization of portion 2 of the electrical steel sheet or roller is cyclically reversed and reestablished by means of magnetizing coil 9 in such a manner

as to produce a symmetrical hysteresis loop whose peak induction is sufficiently close to the saturation point of the given material. The measuring process consists of determining by means of a ratiometer 1 the ratios of $\Phi_H / \Phi_S = B_H S / B_S S = B_H / B_S$. One of the ratiometer coils 1 is connected through rectifier 3, with a sharp linear characteristic which passes through the origin of the coordinates, to measuring coil 4. The other ratiometer coil is connected to measuring coil 5 through a phase-controlled switch 6. Coil 7, placed near the surface of the measured portion, is controlled by switch 8, which operates in synchronism with switch 6 and serves to measure the instantaneous magnetic strength mean for the segment cross section. The operating phase of switches 6 and 8 is controlled by phase shifter 10. Switch 8 closes and opens the circuit of coil 7 at intervals of exactly half a period. The moving-coil instrument 11, connected in series with switch 8, measures the mean current in this circuit, which is proportional to the instantaneous values of the magnetic field strength at the instants the switch operates. This arrangement makes it possible to tune the phase of the switch by means of the phase shifter to the value required for measuring induction for a given value of the field strength. Since the switching in the circuit of measuring coil 5 is synchronized with that of coil 7, the mean current in this circuit will be proportional to the instantaneous current values. Under these conditions the reading of ratiometer 1 will be proportional to the ratio of the induction in the sample for a given field strength, to the saturation induction in the sample.

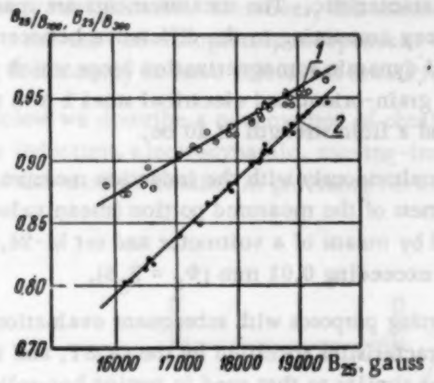

Fig. 3. 1) B_{25}/B_{100} ; 2) B_{25}/B_{300}.

On the basis of the above method the Institute of Metal Physics of the USSR Academy of Sciences has developed equipment for a nondestructive method of checking magnetic induction.

Fig. 2 shows the schematic of this equipment. The magnetic polarity of the measured portion is changed by means of a solenoid whose former carries the following windings:

W_1 and W_2 are two identical measuring windings placed uniformly in the central portion of the former over 1/3 of its length;

W_m is the magnetizing winding distributed uniformly over the whole of the solenoid;

W_c is the control winding in the central part (1/3) of the former.

The solenoid has two openings. One carries the tested object and the other is cut in the central part of the solenoid over 1/3 of its length and carries in a common casing the field-strength measuring coil and two identical compensation coils W_{1k} and W_{2k}.

The compensation windings serve to compensate the magnetic flux in the air gap between the measured sheet and the measuring winding, and is connected in series-opposing with the respective measuring winding.

One pair of such windings is connected through switch 6 to the integrating RC network. The voltage at the output of the integrator is proportional to the instantaneous value of the flux in the measured portion. The field measuring coil is connected through switch 8 to a moving coil instrument.

The phase-controlled switches consist of phase-sensitive transistorized bridge circuits [5] which are controlled by a special square-wave voltage generator 12. A similar bridge circuit controlled by the controlling-coil voltage which is in phase with the emf of the measuring coil serves as a rectifier 3 in the second measuring circuit which is also connected to an integrator whose output voltage in this instance is proportional to the saturation flux. The phase is set by a phase shifter made on the basis of an autotransformer [6].

The voltage ratio at the output of integrators is determined by means of two functional converters of a bridge type which use transistors connected in a circuit similar to that used in ratiometer 1 [7].

The maximum field strength amplitude can be determined by analyzing the relation of ratios B_{25}/B_{300} and B_{25}/B_{100} to the value of B_{25} from the factory test results made on Epstein's apparatus.

It will be seen from Fig. 3 that for a maximum field strength H_{max} = 300 ab/cm the straight-line characteristic B_{25}/B_{max} is much steeper (i.e. the sensitivity is greater) and the dispersion of points is smaller (i.e. accuracy greater) than for a field strength of H = 100 ab/cm.

The instability of B_{300} causes an error in determining the value of B_{25} from the ratio B_{25}/B_{300}, but since the value of B_{300} depends only on the chemical composition of the material (and even then to an insignificant extent),

its value remains constant for batches of articles made from the same brand of steel and deviations do not exceed 1%, which determines the accuracy of this method.

Induction Measurement Results Obtained on Epstein's Apparatus and by means of Ratios B_{25}/B_S and B_{50}/B_S

B_{25}, gauss		Error		B_{50}, gauss		Error	
Epstein's apparatus	B_{25}/B_S method	absolute, gauss	relative, %	Epstein's apparatus	B_{25}/B_S method	absolute, gauss	relative, %
16220	16300	+ 80	0.5	17250	17400	+150	0.9
16150	16150	0	0	17200	17250	+ 50	0.3
16600	16560	− 40	0.2	17640	17740	+100	0.6
17980	17880	−100	0.6	18760	18740	− 20	0.1
18800	18660	−140	0.7	19480	19240	−240	1.2
18880	18930	+ 50	0.3	19750	19750	0	0
19100	19200	+100	0.5	19900	19900	0	0
19370	19200	−170	0.9	19760	19750	− 10	0.1
19150	19200	+ 50	0.3				

In practice a field with an amplitude of 200 ab/cm is sufficient. Measurement results do not depend on frequency or supply voltage variations.

Induction B_{25} and B_{50} was measured on sheets and rollers of cold-rolled transformer steel. The table provides a comparison of the induction measurement results obtained on Epstein's apparatus and by means of the above equipment. A good agreement is maintained over wide ranges approaching 100% variations of thickness until the measurements fall outside the linear portion of the ratiometer characteristic. The measurements are made with an accuracy amounting to the difference between the static and dynamic remagnetization loops which are negligible for grain-orientated electrical steel 1 mm thick at 50 cps and a field strength of 10 oe.

Simultaneously with the induction measurements, the thickness of the measured portion (mean value) was measured by means of a voltmeter and set M-24, with an error not exceeding 0.01 mm ($\Phi_S = B_S S$).

The above equipment can be used both in mass checking for sorting purposes with subsequent evaluation of the sorted metal by means of Epstein's apparatus according to all the characteristics specified by the GOST, and in selective checking for providing samples with mean properties, in a manner similar to that used in testing hot-rolled steel with a coercimeter [8, 9].

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NEW METHOD FOR OBTAINING SEVERAL CURRENT MEASURING RANGES

M. A. Belilovskii

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Atempts made in designing multirange instruments to obtain a single scale for all the ranges, simple switching, several ranges, and a large measurement coverage meet with a number of difficulties. Thus, the well-known method of sectionalized windings and their switching from parallel to series connection [1] shows a good matching of scales, but in practice cannot provide more than three ranges, since for a larger number the switching of the sections becomes very complicated. Moreover, this method only provides one relation of ranges, namely 1 : 2 : 4. Other methods require the use of completely independent windings with different diameters of wire and arbitrary windings, thus making it necessary to have individual scales for each measuring range.

Below we describe a new method of obtaining two current measuring ranges with ratios of 1 : 2 to 1 : 20, suitable for induction, electrodynamic, moving-iron and other systems of electrical measuring instruments [2]. The essence of this method consists in providing for each measuring range a separate winding which is designed in such a

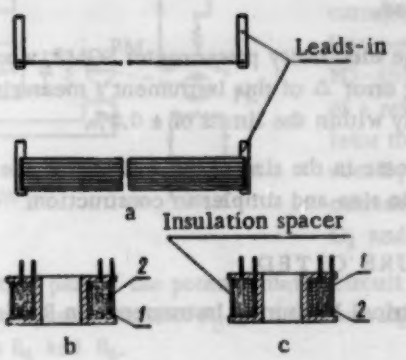

Fig. 1. 1) Cross section of the lower range windings; 2) cross section of the higher range windings.

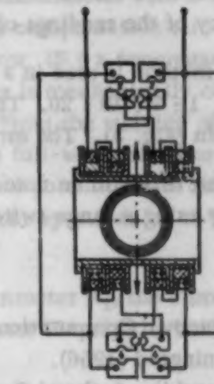

Fig. 2. cross section of the lower range windings; cross section of the higher range windings.

manner that the magnetic field for various measuring ranges remains the same in magnitude, shape and location. This arrangement provides different range ratios with simple switching and very accurate matching of scales. If, however, the new method is combined with the known method of sectionalized windings which are switched from parallel to series connection, then one instrument can be provided with 4 measuring ranges, for instance with ratios of 1 : 2 : : 10 : 20, 1 : 5 : 10 : 50, etc.

In order to obtain similar magnetic fields for different measurement ranges (with the same ampere-turns), the winding is made with wires of the same diameter and the number of conductors proportional to the nominal current value (Fig. 1a); moreover, in each winding there should be the same number of rows and the same number of turns or conductors in a row (Fig. 1b and 1c). For instance, if it is required to have measuring limits of 1 amp and 10 amp, the one-ampere winding will have one conductor, and the 10-ampere winding ten conductors. When placed on a former the two windings must have the same number of rows and turns or conductors in a row.

In order to place the magnetic fields of various ranges in a similar position with respect to the axis of the moving part (only under such conditions is it possible to obtain equal torques), the windings are separated into sections which are arranged in the manner shown in Fig. 2, i.e. the coils which are first wound with lower range sections (Fig. 1b) and those wound with higher range sections (Fig. 1c) alternate.

These sections can be used in order to obtain another two measuring ranges by means of their parallel connection (Fig. 2). If it is necessary to obtain 4 measuring ranges of 1 : 2 : 10 : 20 amp, the first and third of them are obtained by means of the new method, and the second and fourth by means of an appropriate switching of the higher and lower range windings from a series to a parallel connection. Fig. 2 shows the schematic of a 4-range instrument with a plug connector; by inserting the plug into socket 1 the range of 1 amp is obtained, into 2 the range of 2 amp, into 3 that for 10 amp, and into 4 that of 20 amp.

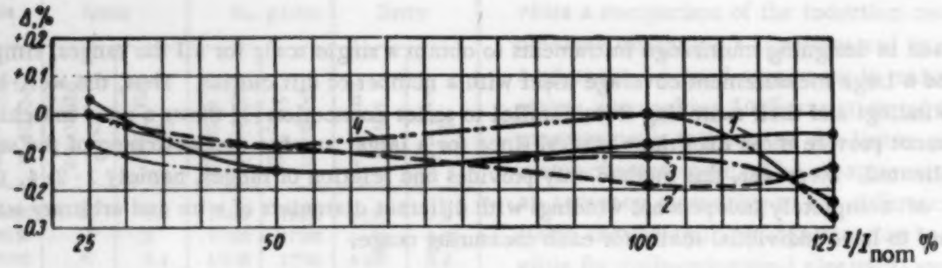

Fig. 3. 1) For a measuring range of 1 amp; 2) the same, 2 amp; 3) the same, 10 amp; 4) the same, 20 amp.

The four measuring ranges are obtained in the above method by means of the most simple switching, and the range ratios can be most varied (1 : 2 : 5 : 10; 1 : 2 : 10 : 20; 1 : 2 : 15 : 30; 1 : 2 : 25 : 50, etc.). Moreover, high matching accuracy of the readings of all ranges is obtained.

The above method is used in a reference multirange electricity power meter SOMP, whose measuring ranges have the ratios of 1 : 2 : 10 : 20. The relative matching error Δ of this instrument's measuring ranges is shown in the attached graphs (Fig. 3). The error lies approximately within the limits of ± 0.1%.

In conclusion it should be noted that a certain increase in the size of the instrument due to separate windings is compensated by using a range switch which is smaller in size and simpler in construction.

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MEASURING THE POWER AND QUANTITY OF ELECTRICITY IN ELECTROLYTIC CIRCUITS

N. M. Rudnyi and V. V. Maslovskii

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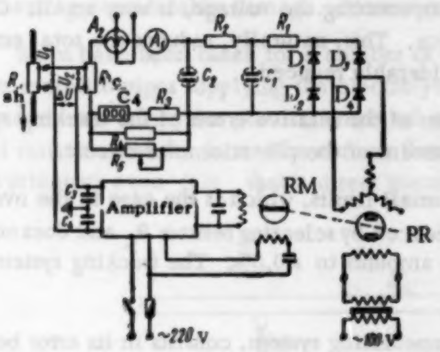
The requirements for accuracy in measuring current, the quantity of electricity, power and energy consumption in dc circuits have greatly increased due to the increasing amount of power and direct current used by installations in the electrolytic industry. Methods have recently been developed for measuring large direct currents by means of groups of shunts [1]. The error of such devices is small but the output signal only amounts to 60-80 mv. Numerous attempts to produce accurate and reliable ampere-hour meters to work on such small output voltages have been unsuccessful.

The moving-iron ampere-hour meters type M-640 produced by our industry are intended for use with dc converters. For normal operation of these meters a voltage of some 3.5 v is required, thus making it impossible to feed them direct from the shunts.

The Institute of Automation of the Ukr. SSR Gosplan (State Planning Committee) has developed a compensation device for measuring the quantity of electricity and power in dc circuits. By means of this device the voltage drop across the shunt or groups of shunts is converted into a proportional direct current.

The device is intended to work in conjunction with the type IPT-100,000 system, which is intended for measuring direct current up to 100,000 amp, has passed its production testing, and has been installed in the Dnepr titano-magnesium plant.*

The registering instrument in this device consists of a type M-640 ampere-hour meter or an electrodynamic wattmeter. In the latter case the voltage winding of the wattmeter is fed through a multiplying resistor from the voltage across the bank of electrolytic baths. Thus the instrument readings become proportional to the power consumed by the electrolytic circuit.



If it is necessary to measure, in addition to the quantity of electricity, also the electrical energy in the electrolytic circuit, the wattmeter in the circuit should be replaced by an electrodynamic electricity meter.

The device, whose schematic is shown in the figure attached, consists of an automatic potentiometer with a variable operating current. The potentiometer compensation circuit is fed from a low-power potential regulator PR (a noncontact selsyn type BD-404A). The selsyn rotor is mechanically coupled to the rotor of a reversible motor RM. From the winding of the potential regulator the voltage is fed to a full-wave rectifier which consists of diodes $D_1 - D_4$ and which feeds the potentiometer circuit. The rectified current ripple is smoothed out by means of an RC-filter (R_1, R_2, C_1 and C_2).

The compensation part of the potentiometer circuit consists of a milliammeter A_1, the current winding A_2 of the wattmeter, the comparison resistor R_c, and the moving-iron electricity meter EM with its building-out resistor R_3 and shunt resistors R_4 and R_5.

The drop in voltage U_2 across the comparison resistor R_c is compared to the output voltage U_1 of the group of shunts R_{sh} and the voltage difference ΔU is fed to the input of the amplifier. The amplified signal operates the reversible motor RM which turns the selsyn rotor until the voltage drop across the comparison resistor becomes equal to the voltage across the terminals of the group of shunts.

Thus, the current in the potentiometer circuit and, hence, the current which is flowing through the millivoltmeter and the series windings of the wattmeter and the electricity meter, is directly proportional to the voltage drop across the group of shunts.

Resistors R_3, R_4, and R_5, which are connected in series and parallel with the electricity meter, serve to reduce the variations in the impedance of the circuit when the meter armature is operated and to match the nominal values of the electricity meter and ammeter currents.

The amplifier input is connected to capacitors C_3 and C_4 which reduce the stray interference signals.

Tests of a model of this device have shown that the current flowing through the circuit of resistor R_c is proportional to voltage U_1 with an error not exceeding ± 0.1%. It has been established that the operating accuracy of the tracking system is not affected by the nonlinear variation of the selsyn output voltage with the rotor's angle of rotation, the instability of the wattmeter circuit resistance, the filter or the measuring instruments.

* Engineers N. K. Tkachenko and L. K. Chernova participated in the tests and adjustments of the device.

The device uses a mass produced amplifier from potentiometer type ÉPP-09 with a threshold of sensitivity of the order of 20 μv. The values of the interstage coupling capacitances of the amplifier have been reduced in order to raise its speed of operation.

The moving parts of the device (the motor and selsyn rotors) possess a considerable moment of inertia if there is a small friction in the bearings. It was therefore necessary to provide the amplifier with a nonlinear velocity feedback which raises the system's stability near the balance position.

The operating time between zero and the maximum current value (100 ma) amounts to 3 sec in the potentiometer circuit, hence the device is suitable even for measurements in which the measured current is unstable with time, for instance, in the electrolysis of aluminum.

If the primary winding of the potential regulator is fed through a voltage transformer from the mains supplying the electrolyzer rectifiers, current variations in the electrolyzer and potentiometer circuits will occur virtually simultaneously and the moving part of the tracking system will not respond to these variations, since voltage compensation will then occur automatically. The reversible motor rotor turns in synchronism with the variations in the electrolytic circuit resistance, which occur relatively slowly.

With the actual nonlinear relationship between the current in the electrolytic circuit and the mains supply voltage, the potential regulator's rotor angle of rotation, required for compensating the voltage, is very small. Owing to this fact it becomes possible to neglect the dynamic error of the device. This, naturally, reduces the total error of the device, since the lag in the unbalance voltage operation is thus considerably reduced.

The relative error of the whole device is determined by the sum of the relative errors of the tracking system shunt, the electricity meter (or wattmeter) and the error in the adjustment of the potentiometer circuit.

In the case when the electrolytic circuit current varies within small limits, which is the case in the overwhelming majority of installations, the systematic error of the shunt can be reduced by selecting resistor R_c and does not exceed ± 0.2%. The error of the electricity meter M-640 used in the device amounts to ± 0.5%. The tracking system's error does not exceed 0.1%. Thus, the total error does not exceed 1.0%.

The advantage of the above device, similar to any current compensating system, consists in its error being almost completely independent of the instability of the amplifier characteristic.

Additional errors may arise in the case where the period of the low-frequency electrolytic current oscillations approaches the operating time of the tracking system. But since the oscillations of the measured current amount to a few percent, the error will not exceed a few hundredths of one percent.

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INSTRUMENT FOR MEASURING DIRECT CURRENT IN ELECTROLYTE JETS

P. P. Pirotskii and N. N. Shvetsov

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 43-45, December, 1961

Modern equipment for the electrolysis of aqueous solutions are fed with a rectified current of several tens of thousands of amperes at a voltage of 800 v across the ends of a bank of electrolytic baths. Each bank contains from 100 to 200 or more baths connected in series. Each bath 4 (Fig. 1) is mounted on supporting insulators 1 and is continuously filled with a jet of fresh electrolyte (in Fig. 1 the jets are represented by dotted lines) from a common manifold 2. The spent electrolyte runs out in a jet into a common trough 3.

The electrolyte jets have a sufficiently high conductivity to form complex electrical circuits along which leakage currents I_1 flow. These currents vary from fractions of an ampere to a few amperes. The leakage currents penetrate along the jets and the trough into the earth and corrode metallic and reinforced concrete structures of workshops, thus causing considerable damage. Moreover, they also endanger human beings.

Steps have been taken for a number of years to reduce the leakage currents in electrolytes. Thus, in many plants metallic pipes supplying the electrolyte to the baths are replaced by faolite pipes, the sectionalized troughs are made from a vinylite plastic compound or ceramic materials, and interceptors are inserted for raising the electrical resistance of the jets. The current flowing in the jets was, until recently, evaluated by indirect methods [1, 2]; some scientists even felt that a direct measurement of currents in the electrolytic jets was impossible [1].

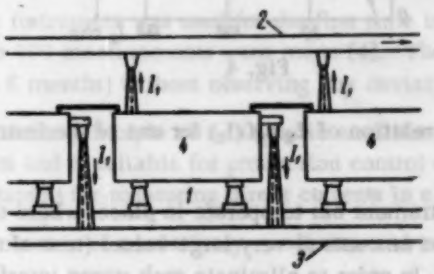

Fig. 1

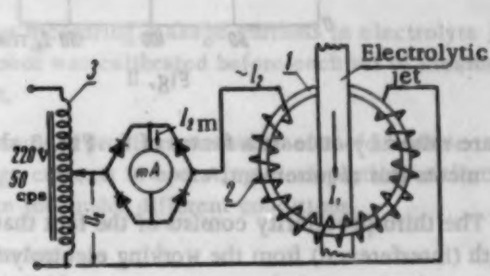

Fig. 2

Direct measurements of currents were started in 1959 when the authors of this article constructed a direct-reading instrument for this purpose at the Dnepropetrovsk chemicotechnological institute.

The instrument's schematic and principle of operation. The instrument (Fig. 2) consists of a simple magnetic amplifier adapted for measuring small direct currents which flow in the jets.

The permalloy toroidal core 1 with its ac winding 2 is mounted in such a manner that the electrolytic jet which carries direct current I_1 can flow freely through the opening in the core. Thus the jet becomes the dc winding of the core (control winding) with a number of turns equal to W = 1. The core thus becomes magnetized simultaneously by the direct current I_1 and the alternating current I_2 which is fed to winding 2 from autotransformer 3. Voltage U_2 is maintained during measurements at a constant value, and therefore alternating current I_2 increases with a rise in direct current I_1.

The moving-coil milliammeter mA measures the mean rectified current I_2. The instrument's scale is calibrated empirically in values of current I_1.

Despite the fact that this method is well-known and widely used in saturation chokes, magnetic amplifiers, dc measuring transformers and other devices, its application for measuring small direct currents in electrolyte jets has certain peculiarities.

Its first peculiarity consists of the fact that the number of turns in the control winding equals $W = 1$ and cannot be increased, since the conducting body consists of the electrolyte jet. The diameter of the core, owing to structural considerations, cannot be made smaller that 5-6 cm. Hence, the magnetic field strength due to the leakage current is very small. Thus, for a direct current in the jet of 0.1 to 3.0 amp the field strength H_1 in the core amounts to 0.005 to 0.15 amp/cm.

For such small magnetizing field strengths it is impossible to design a dc measuring transformer operating with a condition of equal ampere turns $I_2W_2 = I_1W_1$. It is known that in order to obtain the above operating condition the dc field strength H_1 for permalloy cores must not be less than 0.4 amp/cm [3]. Hence, the instrument uses the principle of a simple magnetic amplifier in which $I_2W_2 \neq I_1W_1$. This makes it possible to use one core only, thus simplifying the instrument's construction.

The second peculiarity consists of the fact that the instrument must be highly sensitive, since it is intended for measuring small currents (from 0.1 amp up). For this purpose the parameters of the instrument's electrical and magnetic circuits must be selected in such a manner that for variations of the direct current I_1 within given limits (for instance, from 0.1 to 3.0 amp) the coil impedance Z_2 variations are raised by at least a factor of 5. Fig. 3 shows the relation of $Z_2 = f(I_2)$ for one of the instrument's models which meets this requirement.*

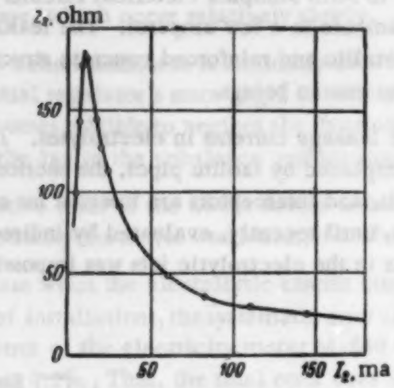

Fig. 3

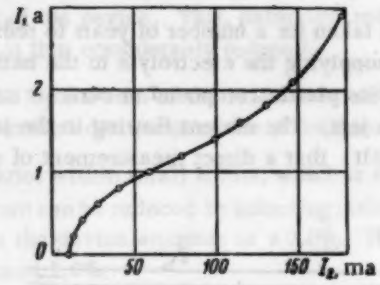

Fig. 4

The third peculiarity consists of the fact that the instrument has to operate in places where the magnetic field strength (interference) from the working electrolytic current amounts to very large values (tens of amp/cm), since the current in the supply buses attains tens of kiloamperes. In order to eliminate such strong interference a treble screening of the core is provided.

Instrument's design and testing. The instrument consists of two parts. The first part consists of the core with its windings placed in a special protective jacket with a handle for holding the core during measurements in such a position at the side of the electrolytic baths as to make the jet flow through its opening. The jacket has a treble magnetic screen protecting the core from the effect of external magnetic fields. The second part of the instrument consists of a milliammeter with shunts, a rectifier, and an autotransformer. All the components are mounted in a portable case.

The basic data of the instrument consist of: a core, external diameter – 100 mm and an internal diameter – 60 mm, a tape width of 20 mm (permalloy), 120 turns in the ac winding, ac input voltage of 1.9 v,** and an initial current of 10 ma (field current). The instrument uses a Grade 0.5 milliammeter type LM-1 with a scale of 50 ma (with a hunt) and a germanium rectifier type DGTs-21.

*Curve $Z_2 = U_2/I_2$ has been plotted for $I_1 = 0$, $f = 50$ cps and a U_2 increasing from zero. It is practically identical with curve $\mu = f(I_2)$ and provides the main requirement specified for the core, namely the sharp drop in μ after its maximum has been reached.

**Voltage U_2 is found in plotting the curve of Z_2 (Fig. 3) when Z_2 (and the μ of the core) attains a maximum. This also determines the beginning of the dc milliammeter scale (in the above instrument $I_2 = 10$ ma for $I_1 = 0$).

The instrument calibration curve is shown in Fig. 4. For leakage current variation from 0 to 0.9 amp the milliammeter mA readings vary from 10 to 50 ma. For leakage currents exceeding 0.9 amp the milliammeter scale was extended by means of shunts.

Since the instrument has one core, there is the danger of the readings becoming distorted by ac currents induced in the jet. The instrument readings may also be effected by variations in the supply voltage and frequency, and the ambient air temperature.

In order to determine the effect of the above factors the instrument was carefully tested under laboratory conditions. These tests have shown that voltage U_2 variations in the limits of ±10% from the nominal value (due to supply voltage variations after the value of U_2 has been set) change the instrument readings by a maximum of ±2.5%. Mains frequency variations of ± 0.5% do not affect the instrument readings.

The effect of the induced ac emf on the instrument readings is negligible, since that emf is very small (less than 0.016 v) and the resistance is high (of the order of 100-200 ohm). Experiments have shown that even a short-circuited turn of 0.3 ohm placed on the core during calibration produces a maximum reading error of ±3.0%.

The instrument was calibrated in an ambient temperature of + 20°C. The raising of this temperature up to + 35°C did not vary the instrument readings of small currents I_1 (up to 0.8 amp); for currents up to 3 amp it produced maximum variations of ± 2.5%.

The above errors are well within the tolerances suitable for checking leakage currents.

In order to determine the direction of the measured current the core is provided with a second winding (not shown in Fig. 2) which is fed from a flashlight battery. By switching in the battery during measurements it is possible to determine the direction of the current in the jet.

CONCLUSIONS

The above instrument was used for the first time in 1959 for measuring leakage currents in electrolyte jets at two plants. Over 300 measurements were made [4]. The instrument was calibrated before each set of measurements (10 times during 6 months) without observing any deviations in it.

Designed on the principle of a magnetic amplifier, the instrument provides measurements of small dc currents in electrolyte jets and is suitable for production control of leakage currents in operating electrolytic installations. It can also be adapted for measuring direct currents in electrolyte jets under different conditions.

The instrument is of a relatively small size and is simple to use.

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METHOD FOR MEASURING INDUCTANCES AND CAPACITANCES WITH CURRENTS DISPLACED BY 90°

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Rumanian People's Republic

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 45-47, December, 1961

The article deals with a method for measuring inductances and capacitances based on a circuit in which a 90° phase difference is established between currents flowing through two branch circuits.

Let us examine a circuit whose schematic is shown in Fig. 1. Here L and C are the inductance and capacitance under comparison, $\underline{r}$ is the resistance of the inductance coil, R and R_B are the resistances, one of which must be variable.

Let us assume that the circuit is fed with a sinusoidal voltage

$$U=\sum_{n=1}^{n=\infty}\sqrt{2}\ U_n \sin(n\omega t+\psi_n).$$

Having denoted by I_{An} and I_{Bn} the harmonics of currents I_A and I_B which flow in branches A and B, we can write the following relations:

$$\dot{I}_{An}=\frac{\dot{U}_n}{R_A+j\omega nL}, \tag{1}$$

$$\dot{I}_{Bn}=\frac{\dot{U}_n}{R_B+\dfrac{1}{j\omega nC}}, \tag{2}$$

where $R_A = r + R$.

In order to make the phase difference between these harmonics equal to 90°, the following relation must hold:

$$\dot{I}_{An}=-jK\dot{I}_{Bn}, \tag{3}$$

where K is any real number, or

$$\frac{\dot{U}_n}{R_A+j\omega nL}=-jK\frac{\dot{U}_n}{R_B+\dfrac{1}{j\omega nC}}.$$

By separating the real and imaginary parts we obtain the condition for a 90° phase difference in the form of two equations:

$$R_B=Kn\omega L \text{ and } KR_A=\frac{1}{\omega nC}, \tag{4}$$

whence

$$L=CR_A R_B. \tag{5}$$

If the circuit parameters are chosen in a manner to satisfy condition (5), then for any value of $\underline{n}$ there will be a real value of K for which condition (4) will be met. Hence, equation (5) is a necessary and sufficient condition for each harmonic of current I_A to be shifted in phase with respect to the corresponding harmonic of current I_B by

an angle of 90°. The above property makes it possible to use the circuit for measuring inductances by means of a standard capacitance, or capacitances by means of a standard inductance.

In fact, by adjusting one of the resistors until the phase difference between currents I_A and I_B becomes equal to 90°, it is possible to find the required value from (5). It is important to note that if the inductance and capacitance incorporated in the circuit do not depend on frequency the shape of the supply voltage will not affect measurement results.

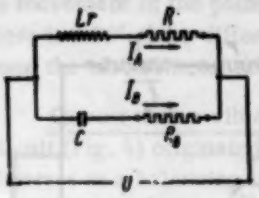

Fig. 1

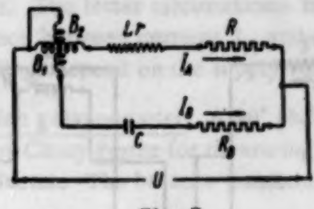

Fig. 2

Evaluation of measurement errors. Errors in measuring L consist, in the first place, of the errors in the circuit parameters which serve to calculate the required quantity, and in the second place, of errors in setting a 90° phase difference.

The relative measurement error $\Delta L / L$, due to parameter errors, can be evaluated from the well-known relation

$$\frac{\Delta L}{L}=\frac{\Delta C}{C}+\frac{\Delta R_A}{R_A}+\frac{\Delta R_B}{R_B},$$

where ΔC, ΔR_A, and ΔR_B are the errors in the capacitance and resistors.

In order to evaluate the error in setting a 90° phase difference let us note that the following equality must be met: $\varphi_{An}+\varphi_{Bn} = 90°$ (where φ_{An} and φ_{Bn} are the differences between the voltage and current of the n-th harmonic in branches A and B, respectively).

The error in setting a 90° phase difference is equivalent to the error in setting the required value of angle φ_{An}.

But $L=\frac{R_A}{n\omega}\tan\varphi_{An}$ and $\frac{\Delta L}{L}=\frac{\Delta R_A}{R_A}+\frac{\Delta n\omega}{n\omega}$

$$+2\frac{\Delta\varphi_{An}}{\sin 2\varphi_{An}}. \tag{6}$$

The last term of (6) is the error due to an inaccurate setting of angle φ_{An}. It will easily be seen that this error is at a minimum when $\varphi_{An}=\varphi_{Bn} = 45°$. A deviation of φ_{An} from 45° increases the effect of error $\Delta\varphi_{An}$ on the measurement results. This effect becomes excessive when φ_{An} is smaller than 15° or larger than 75°.

It should be noted that φ_{An} cannot approach 45° for all the harmonics simultaneously. However, if the condition $\varphi_{An}\approx 45°$ is met for the fundamental, the errors due to an inaccurate setting of the 90° phase difference between the higher harmonics will be small, since the amplitudes of higher harmonics are small as compared with the fundamental.

Application of an electrodynamic instrument for indicating a 90° phase difference. Fig. 2 shows a circuit in which an electrodynamic instrument is used for indicating a 90° phase difference between currents I_A and I_B.

It is known that the mean value of the torque applied to the moving part of an electrodynamic instrument whose windings carry a sinusoidal current is equal to

$$M=f(\alpha).\sum_{n=1}^{\infty} I_{An}\cdot I_{Bn}\cos\varphi_n.$$

where $f(\alpha)$ is a function of the moving part rotation angle α; I_{An} and I_{Bn} are the effective values of the current harmonics flowing respectively through the windings of the moving and stationary parts of the instrument; φ_n is the phase shift between them.

The torque and hence the deflection of the moving part is equal to zero when $\varphi_n = 0$ for all the current harmonics. Inductance can be measured very rapidly if C and R_B are selected in such a manner that angle $\varphi_{B_1} = 45°$.

and the instrument is set to zero by means of variable resistor R_A. This can only be attained if the Q-factor of the coil is sufficient high (larger than unity).

When an electrodynamic instrument is used it is necessary to take into account both the resistances of its windings and their inductances. Although the latter are small, the errors due to them limit the range of the method's application.

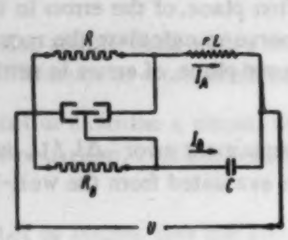

Fig. 3

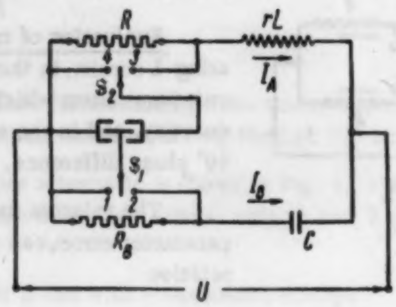

Fig. 4

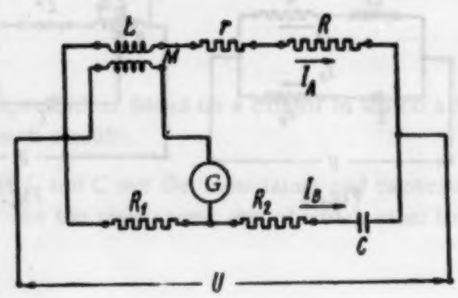

Fig. 5

By taking into account inductances l_1 and l_2 of the coil's moving and stationary parts, respectively, it is possible to obtain the condition for a 90° phase difference in the following form:

$$L = R_A R_B C \frac{1}{1 - C l_2 \omega^2} - l_1.$$

For low frequencies and $C < 10$ μf the quantity $C l_2 \omega^2$ can be neglected.

The experimental application of the method carried out by the author of this article by means of a sensitive wattmeter "Metra" has shown that a measurement error not exceeding 1% can be easily obtained.

Use of a quadrant electrometer. Fig. 3 shows a circuit in which a quadrant electrometer is used for indicating a 90° phase difference.

For the connection shown in the schematic the mean torque applied to the moving part of the electrometer is equal to

$$M = K \frac{1}{T} \int_0^T [(R i_A)^2 + 2 R R_B i_A i_B] \, dt,$$

where K is the coefficient depending on the electrometer parameters; i_A and i_B are the instantaneous values of currents I_A and I_B; T is the period of the supply voltage.

By resolving currents i_A and i_B into their harmonics and integrating, we obtain

$$M = K \left[R^2 \sum_{n=1}^{\infty} I_{An}^2 + 2 R R_B \sum_{n=1}^{\infty} I_{An} I_{Bn} \cos \varphi_n \right]. \tag{7}$$

where I_{An} and I_{Bn} are the effective values of the n-th current harmonics; φ_n is the phase difference between the current harmonics.

For a 90° phase difference between the harmonics the second term in (7) is equal to zero.

In order to eliminate the error which may be produced by the first term of (7) it is recommended to measure by means of the circuit shown in Fig. 4 in the following manner:

1. Switch S_1 is thrown to position 1 and switch S_2 to position 4. The quadrant electrometer pointer will then be set to zero.

2. Switch S_2 is then thrown to position 3. The pointer will be displaced by a value proportional to

$$KR^2 \sum_{n=1}^{\infty} I^2_{An}. \tag{8}$$

3. Switch S_1 is then thrown to position 2 and resistor R_B is adjusted until the throwing of switch S_1 produces no movement in the pointer. The latter circumstance indicates that the second term of (7) is equal to zero, and hence there is a 90° phase difference between currents I_A and I_B. The circuit should be supplied through a voltage stabilizer since the electrometer readings depend on the supply voltage.

Circuit with a vibration galvanometer. A 90° phase difference between currents also exists in the well-known circuit (Fig. 5) originated by Carey Foster for measuring mutual inductance. In this instance a vibration galvanometer G serves as a balancing inductor. The balance conditions of the circuit are expressed by the equation

$$\frac{M}{C} = R_A R_1; \quad \frac{M}{L} = \frac{R_1}{R_B}, \text{ whence } L = CR_A R_B, \tag{9}$$

where M is the coil mutual inductance;

$$R_A = r + R; \quad R_B = R_1 + R_2. \tag{10}$$

It will easily be seen that providing these conditions are met all the harmonics will be balanced and the phase difference between the harmonics of currents I_A and I_B will be equal to 90°.

Contrary to circuits with the electrodynamic instrument and a quadrant electrometer, the circuit with a vibration galvanometer requires for its balance not only a 90° phase difference between currents I_{An} and I_{Bn}, but also an equality of the harmonic voltage amplitudes of $I_{An} n\omega M$ and $I_{Bn} R_1$. In this circuit the zero reading on the indicator is obtained, therefore, by adjusting two resistors instead of one.

CONCLUSIONS

Circuits with a 90° phase difference between currents can be used for a rapid and sufficiently accurate measurement of inductances and capacitances both with sinusoidal and nonsinusoidal supply voltages.

At present these instruments are used by the author at the electrical measuring laboratory of the Jassy polytechnical institute for measuring not only linear inductances but also inductance coils with steel cores and capacitors with losses.

CHECKING dc WATTMETERS BY THE VOLTAGE SUMMATION METHOD

I. N. Osher

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 48-49, December, 1961

The checking of wattmeters consisting of separate measurements of the voltage and current by the compensation method with subsequent multiplication of the data thus obtained has well-known defects.

dc power can be measured in separate current and voltage circuits directly, without individual current and voltage measurements by the voltage summation method.

It is known that in general the measurement of power by the sum and difference of voltages proportional to the current and voltage is taken as the basis for the operation of thermoelectric, electrostatic and tube wattmeters.

In 1959 instruments were patented for checking wattmeters by means of the voltage summation method [1] and in 1960 an article was published describing briefly such an instrument [2]. However, no analysis of the voltage summation method has appeared either in our own or foreign literature.

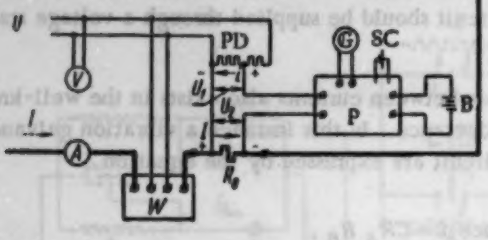

Fig. 1. A is the control ammeter; V is the control voltmeter; W is the tested wattmeter; PD is the potential divider; R_0 is the reference resistor; G is the galvanometer; P is the potentiometer; SC is the standard cell; B is the battery.

Wattmeters are checked by means of this method according to the schematic shown in Fig. 1. The characteristic of this method consists of making voltages U_1 and U_2 approximately equal and measuring their sum by means of potentiometer P.

Let us examine the identity

$$4U_1U_2=(U_1+U_2)^2-(U_1-U_2)^2. \tag{1}$$

For a small difference between U_1 and U_2 it is possible to assume that

$$U_1U_2=\frac{(U_1+U_2)^2}{4}. \tag{2}$$

The error of this equality, i.e. the error of the voltage summation method, can be represented by the following formula:

$$\Delta=\frac{(U_1-U_2)^2}{4U_1U_2}\cdot 100\%. \tag{3}$$

When power is measured by means of the circuit shown in Fig. 1 we have

$$U=\frac{U_1}{M} \text{ and } I=\frac{U_2}{R_0}, \tag{4}$$

where M is the reciprocal of the voltage ratio D, i.e. the number by which the primary voltage has to be multiplied in order to obtain the secondary voltage; U is the actual value of the voltage; I is the actual value of the current.

The actual value of the measured power is

$$P=UI=\frac{U_1\cdot U_2}{MR_0}. \tag{5}$$

From (5) and (2) we obtain

$$P_{\mathrm{mp}}=\frac{(U_1+U_2)^2}{4MR_0}=\frac{U_\alpha^2}{4MR_0}, \tag{6}$$

where U_α is the total voltage measured by the potentiometer for a wattmeter reading of α.

Since U_1 and U_2 are set to be approximately equal, it is possible to assume that

$$U_1=U_{\mathrm{m}}\cdot(1+0.01\cdot\varepsilon);\quad U_2=U_{\mathrm{m}}\,(1-0.01\cdot\varepsilon), \tag{7}$$

where U_{m} is the arithmetic mean value of U_1 and U_2; ε is the deviation of U_1 and U_2 from U_{m}, expressed in % of U_{m}.

By substituting (7) in (3) we obtain, after transformations, the error of the voltage summation method expressed in % of ε:

$$\Delta = 0.01 \cdot \varepsilon^2 \ \%. \tag{8}$$

The testing current as well as the voltage drop across the reference resistor change when the testing is switched from one wattmeter scale calibration to the next. It is then necessary to change the voltage across the potential divider in order to preserve the condition of the equality of added voltages. Such changing of the secondary voltage is possible if a 4-decade potential divider,* shown in Fig. 2, is used.

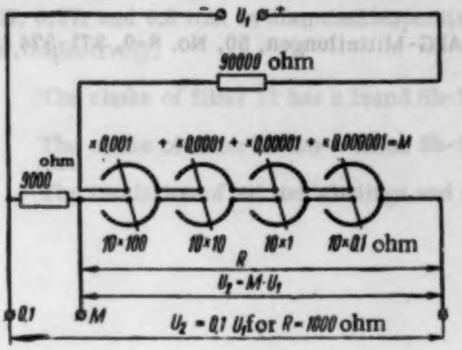

Fig. 2

The resistance on the secondary side of this potential divider can be varied from 0.1 to 1111 ohm in steps of 0.1 ohm. It is advisable to calibrate the scale both in secondary resistance values and in voltage ratios M. The secondary voltage is set by the current, which corresponds to the tested calibration of the wattmeter scale.

The 4-decade potential divider is provided with a tap at 9000 ohm in order to make it suitable for checking voltmeters. If resistance R = 1000 ohm is set on the four voltage divider decades by means of their knobs, and the secondary voltage is taken off the terminals marked 0.1 and +, we shall obtain M = 0.1. The remaining ratios smaller than 0.1 are obtained with the secondary voltage taken off the terminals marked M and +.

The ratio M which should be set on the 4-decade voltage divider when changing from one wattmeter scale marking to the next should be calculated in advance if the wattmeter is being checked according to the schematic shown in Fig. 1. Such calculations for an instrument with a given scale and a given number of calibrations are made but once, and are then used for other instruments with the same ranges and the same number of scale calibrations.

The value of the ratio is determined from the formula

$$M_\alpha = \frac{I \cdot R_0}{U_n} = \frac{I_n \cdot R_0}{U_n N}\,\alpha, \tag{9}$$

where M_α is the value of the ratio which corresponds to the tested scale mark; I_n and U_n are the nominal current and voltage of the tested wattmeter; R_0 is the nominal resistance of the reference resistor; N is the reading of the tested wattmeter which corresponds to nominal current I_n (when the scale calibration corresponds to the number of divisions, N is equal to the number of scale divisions); α is the reading at the checked mark of the scale.

The patented circuits include those in which the current circuit is provided with a special unit of standard resistors of such values that the voltage across the reference resistor does not change when passing from one tested scale mark to the next. This voltage remains equal to that taken off the potential divider.

A reliable operation of the switch should be provided in sets whose current circuit standard resistance changes when the testing is switched from one scale mark to the next. This switch should operate with the current flowing through it during switching in order to provide the operator with a high productive capacity.

CONCLUSIONS

The above voltage summation method has the following advantages as compared with the method entailing separate current and voltage measurements:

a reduction in the required number of components, since it is only necessary to have one potentiometer, one galvanometer, one standard cell, etc.;

*The latest potential divider has been changed; the three higher decades have nine instead of ten resistors each.

the carrying out of power measurements by means of a single compensation of the voltage sum, thus raising the accuracy of measurements by eliminating the error due to separate current and voltage compensations;

a considerable increase in the productivity of labor due to a single compensation and the elimination of the requirement to maintain with high precision the separate current and voltage values.

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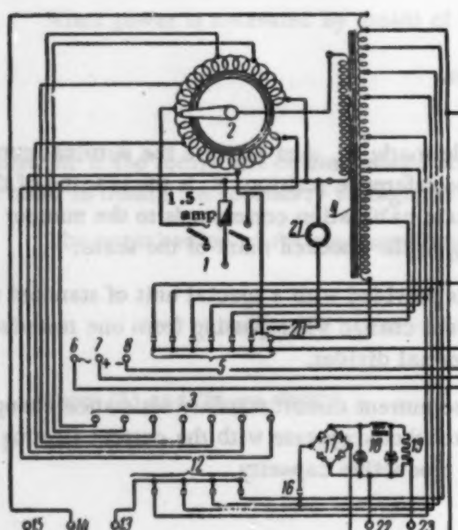
PORTABLE DEVICE FOR CHECKING ELECTRICAL MEASURING INSTRUMENTS

D. D. Knyazev

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 49-50, December, 1961

The portable set provides the testing, in situ, of dc and ac voltmeters, ac ammeters and preliminary testing of single- and three-phase wattmeters (without the possibility of controlling the phase between the current and the voltage), and the adjustment of various relay circuits. The dimensions of the set are 150 × 175 × 300 mm, and its weight is 7.5 kg.

The set operates from 50 cps mains and provides a continuously controlled 50 cps voltage up to 600 v, a 50 cps current up to 250 amp, a rectified voltage up to 600 v, and up to 100 mv. The ripple of the rectified voltages is less than 0.05%. The smoothness of the voltage adjustment amounts to 0.1-0.2% of the output voltage value.



The schematic of the set is shown in the figure attached. It operates from 127 or 220 v mains connected to terminals 1. It is equipped with an adjustable autotransformer (LATR-2a) 2 in order to provide a smooth adjustment of the output current and voltage. Its winding has five intermediate taps, thus supplying at terminals 3 another six unregulated voltages of 30, 75, 100, 150, 220, and 250 v for simplified wattmeter testing. It should be noted that only a simplified wattmeter testing is possible instead of that specified by the Committee's Instruction 184-54, since the set is not fitted with a phase shifter.

The control voltage is fed from the output of autotransformer LATR-2a to the primary winding of a multirange transformer 4, whose secondary winding has ten taps.

It is possible to obtain at terminals 6 and 7 an ac voltage adjustable in ranges up to 2, 5, 15, 75, 150, 300, and 600 v according to the setting of the plug in one of the sockets 5 with switch 9 in the appropriate position. Similarly, dc voltages can be obtained at terminals 7 and 8. These voltages are rectified in bridge circuit 10 consisting of D7Zh diodes, and smoothed-out in filter 11 consisting of a 2 h inductor and four 30 μf, 300 v capacitors. An alternating current can be obtained at terminals 13 and 14 adjustable in ranges up to 0.5, 5, 25, and 50 amp depending on the setting of the plug in socket 12. At terminals 15 and 14 it is possible to obtain an alternating current up to 250 amp from a circuit without any switching.

Moreover, a rectified current up to 0.1 amp and a rectified voltage up to 100 mv can be obtained at terminals 22 and 23 by inserting the plug into socket 16. The rectification is obtained in bridge circuit 17, consisting of D7A diodes, and the smoothing is obtained in filter 18, which comprises two 20 μf capacitors and a 0.3 h choke coil. The rectified voltage is fed from the filter to potential divider 19 whose arms measure 17 and 3 ohm respectively. Interlocking contact 20 and a signal lamp 21 are used as safety precautions when the plug is set to 300 or 600 v.

Let us now provide some data on the transformer and choke coils. The core of transformer 4 is made of brand Sh-30 iron laminations in 25 mm packages. Its primary winding of 1320 turns is wound with 0.41 mm PÉ wire, and its secondary winding with taps at 1900, 1000, 475, 375, 60, 20, 15, 4, and 2 turns is wound with PÉ wire of 0.15, 0.20, 0.23, 0.27, and 0.5 mm in diameter, respectively, and with PBD wire of 1.56, 2.02, 2.02 × 3 and 2.02 × 14 mm in diameter, respectively.

The choke of filter 11 has a brand Sh-21 iron core and a winding of 4600 turns of 0.25 mm PÉ wire.

The choke of filter 18 has a brand Sh-14 iron core and a winding of 1650 turns of 0.29 PÉ wire.

The insulation of all the windings and of the set in general was tested at 2 kv, 50 cps.

PORTABLE THREE-PHASE TESTING EQUIPMENT

I. P. Grishanov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 50-51, December, 1961

The equipment developed by us is intended for testing and adjusting, in situ, single- and three-phase electricity meters, wattmeters, phase meters, ammeters, and voltmeters at commercial frequencies. It can also be used for testing relays of a certain type.

The equipment has 5 current ranges of 0.5, 1, 2, 5, 10 amp, and 3 voltage ranges of 150, 300, 450 v.

The phase between the current and voltage is controlled over a range of 0-360° with a special adjusting device, by means of which the value of the current is also set.

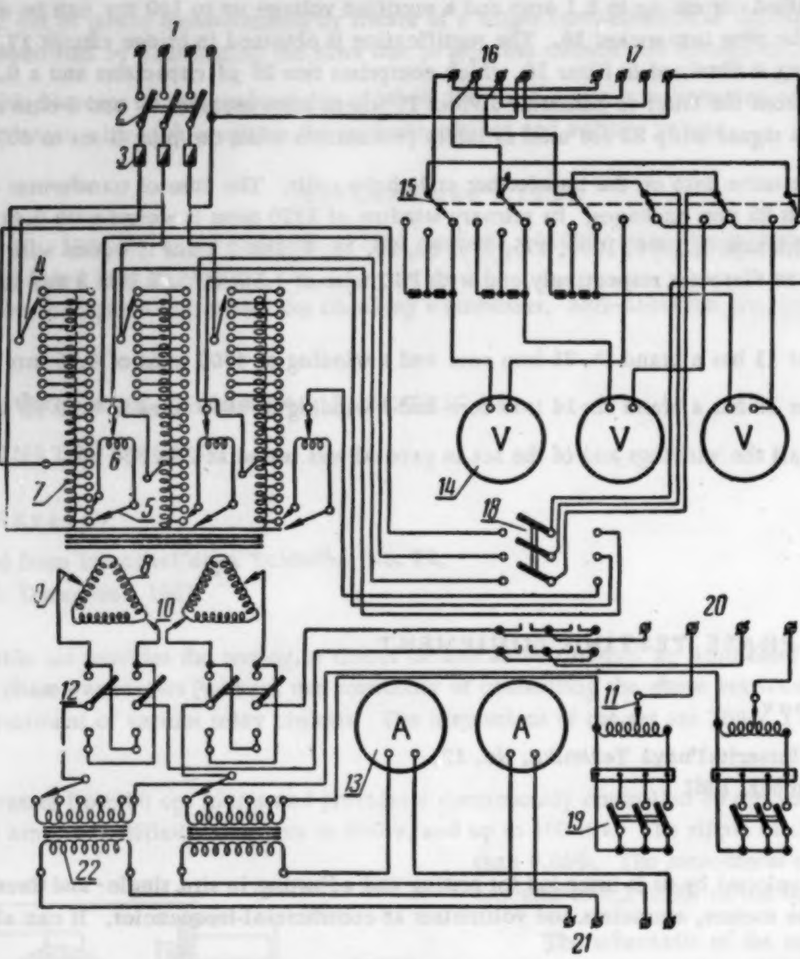
The current is adjusted in the range of 2 to 125%, and the voltage in the range of 2 to 110% of each full-scale reading. The smoothness of adjustment amounts to 0.1% of the respective maximum readings.

The set is made up of normal mass-produced components. The only exception consists of the phase-integrating device, which comprises a three-phase, three-limb power transformer with special transverse 7 and secondary 8 windings. The transformer is rated at 500 w, its high-voltage (primary) winding is of 450-500 v, and its low-voltage (secondary) winding of 10-12 v.

The transformer windings are placed on a special core made in the shape of a three-point star inscribed into a solid ring. The primary windings are wound inside the ring on the star limbs. The windings have up to 20 taps which are connected directly to the multirange switches of voltage regulators 4 and 5. The secondary windings are made in the shape of two separate triangles and are placed on the connecting ring of the core (actually the device has two similar cores placed one above the other, with each triangle located on a separate core).

The equipment is designed for a simultaneous testing of 15 three-phase electricity meters which are placed on a supporting board made at the test location.

The equipment can be supplied from three-phase mains of 110-220-380 v. Its power consumption with 15 electricity meters amounts to 0.35 kva.



1) Input terminals; 2) three-phase 400 v, 10 amp circuit breaker; 3) two amp fuses; 4) and 5) switches for rough and medium step-by-step adjustment of the output voltage; 6) slides for a smooth output voltage adjustment; 7) and 8) primary and secondary windings of the regulating device; 9) 10) and 11) slides for a rough and smooth output current adjustment (with simultaneous variation of the phase angle between the output current and voltage); 12) current switch; 13) and 14) auxiliary rack-mounted ammeters and voltmeters; 15) combined switch for voltage ranges and for switching from line- to phase-voltage measurements; 16) terminals for connecting voltage circuits of the tested instruments; 17) terminals for connecting the voltage circuits of the reference instruments; 18) switch for the current and voltage circuits used in testing relays; 19) switch for connecting into the current circuit resistances of various values; 20) terminals for connecting the current circuits of the tested instruments; 21) terminals for connecting the current circuit of the reference instruments; 22) reference current transformers I-54, whose secondary windings are connected to the total resistance of the auxiliary and reference ammeters and wattmeters.

The equipment is produced in the shape of a case with a hinged lid. Its dimensions are 520 × 370 × 190 mm, and its weight is 18 kg. The weight of the phase-integrating device is 6.5 kg.

The practical application of this equipment on the Sverdlovsk railroad produced satisfactory results.

DIFFICULTIES IN TESTING ELECTRICITY METERS

B. A. Bliznyuk

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 52-53, December, 1961

There are over 650 three-phase and over 1500 single-phase electricity meters of various types at the Yuzhnyi mineral concentration plant. On the basis of the experience in their use we consider that Instruction 195-54 for testing electricity meters completely meets the requirements for technical and commercial power consumption metering. In fact, all users of electrical power without exception work below the maximum load or, in extreme cases, at nominal loading, i.e. the electricity meter current circuits never operate at more than 5 amp. The only exception is provided by starting conditions; however, they are very short (the longest starting of 28 sec is provided by the exhauster motors $P_n = 2{,}000\,kw$).

On the basis of what considerations does Instruction 195-60 specify the testing of electricity meters at loads of 120, 150, 200 and even 400% above the normal? It could possibly be expedient for electricity meters used by consumers who, owing to the nature of their production process, have numerous and long starting periods or overloads. Neither is it clear why the checking of electricity meters at 5% of the nominal load has been introduced, since at this load the three-phase electricity meters are difficult to adjust, and the single-phase meters virtually cannot be adjusted.

The fulfillment of the requirements specified by Instruction 195-60 presents the following difficulties.

The raising of the load in order to check electricity meters at 200-400% of their nominal value requires the reequipment of test racks, which leads to additional expenditure and the withdrawal of the equipment from operation for a certain time.

The extension of the adjustment ranges of the electricity meters results in more time spent on testing the meters, i.e. it leads to a larger number of operators or the disruption of the testing plan.

We consider, therefore, the requirements stipulated in Instruction 195-60 to be incorrect; neither do we agree that electricity meters type IT Grades 1 and 2 should be withdrawn from use, since we have found them to possess excellent qualities; they can be easily adjusted and are reliable in operation, whereas the new electricity meters types I-43 and I-44 are difficult to adjust.

Editorial Note. Electricity meters of the new design retain their grade of accuracy and can work for a long time over a wider range of loads (up to 300% and more) than meters of the old design.

Instruction 195-54 does not stipulate the testing of electricity meters at loads which are higher than the normal and are catered for in the design, thus providing a considerable loss to our national economy. The users of electricity meters could not select them for new installations on the basis of their overload capacity, since the overload part of the meter characteristic was not tested after repairs. They selected meters with a nominal current equal to the maximum load current instead of chosing meters with a maximum current, at which their grade of accuracy is not impaired, equal to the maximum load current. With such an incorrect choice the overload capacity of meters was not utilized, thus lowering the accuracy in measuring small loads.

If the meter error at a load 200% of the nominal meets the GOST (All-Union State Standard) requirements stipulated for each grade, the meter's nominal current can be half the maximum load current.

The choice of meters with a raised nominal current often leads to an underestimation of the consumed energy. Let us give an example. A 220 v, 10 amp meter is used to register the consumption of one 25 w bulb which produces a load slightly in excess of 1%. Under such conditions the underestimation of the consumed energy may amount to tens of percent.

The accuracy of meters at small loads rises with a reduction in their nominal current for a given load. It is, therefore, necessary to select meters on the basis of their overload capacity.

The need to produce directly connected meters with a high overload capacity has been confirmed repeatedly by a wide circle of electricity consumers when the standards for electricity meters were discussed before their drafting (GOST 6570-53 and GOST 6570-60).

Instruction 195-60 does not require it but rather permits the checking of the new design electricity meters at loads above 100% for single-phase and above 120% for three-phase meters. It concedes the right to test meters at such high loads and, therefore, the adjustment of meters after repairs must be as thorough as during their manufacture.

The difficulties due to increasing the volume of work in checking meters were taken into account when Instruction 195-60 was drafted and it stipulates, therefore, only a minimum number of loads at which the meters which are in service should be tested, namely, at three loads for cos $\varphi = 1$ and at one or two loads (for three-phase meters) at cos $\varphi = 0.5$. In issuing Instruction 195-60 an error has been made which which will be corrected in the next normal reissue of the Instruction, by stipulating that, after repairs, tests should be carried out with loads specified for meters which are in use and not with loads specified for manufactured meters. The agency which carries out the testing can, on its own initiative, chose loads at which a given meter is to be tested.

Testing of meters at 200, 300, and even 400% of their normal load does not require a reequipment of the test racks as indicated by B. A. Bliznyuk, since the racks are normally made for currents at least up to 50 amp.

The great shortcoming of Instruction 195-54 consists of its provision for an incomplete repair of meters. Thus, a meter manufactured with a small effect of the power factor on its readings could, after repairs, have any large random effect of cos φ on its readings, since the regulation did not insist on appropriate testing, and allowed the meter to be stamped as "checked for cos $\varphi = 1$."

Discontinuation of the production of electricity meters type IT requires no explanation, since they do not meet the GOST requirements. As far as the difficult of adjusting meters IT-43 and IT-44 is concerned, it should be specifically stated which adjustment elements are unsatisfactory, and whether it is difficult to adjust by means of the magnet, phase-shifter or the friction compensator. Such detailed statements will provide the possibility of raising the question with the manufacturing plant.

METHOD FOR CHECKING AND MEASURING MICROPHONIC NOISE IN ELECTRON TUBES

Z. V. Magrachev

Translated from Izmeritel'naya Tekhnika, No. 12,
p. 53, December, 1961

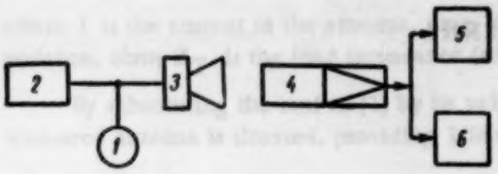
Particular attention should be paid in designing amplifying devices with a sensitivity of the order of 1 microvolt to microphonic noise due to mechanical and acoustical effects on electron tubes. We have found that microphonic noise is present not only at low frequencies of the audio range, but also at frequencies of the order of 10-20 kc, depending on the structure of the tube and the technology of its manufacture. Tube noise varies between individual samples and with the aging of tubes.

It is possible, as a rule, to eliminate low-frequency microphonic noise by means of efficient damping and a suitable structure of tubes. Microphonic noise of 100 cps and higher is, in the majority of cases, due to acoustical vibrations whose screening is very difficult (music, singing, speech, industrial noise).

Below we describe a method for checking and measuring such noise for the purpose of developing tubes according to their noise characteristics and by their sensitivity to acoustical interference. According to this method (see figure) the output of audio-oscillator 2 is measured on voltmeter 1 and fed to loudspeaker 3 placed at a set distance from tested tube 4, which serves as an input tube of a highly-sensitive amplifier. The sockets for the tested input tubes are mounted on normal rubber or spring dampers in order to avoid the transmission of possible mechanical vibrations.

The amplifier should provide, in the range of 100 cps-20 kc, measurement of signals with a voltage not less than 10 μv in aperiodic amplification, and not less than 1 μv in selective amplification with the possibility of feeding the signal to the millivoltmeter 5 or the oscilloscope 6.

The control grid of the tested tube (amplifier input) must be short-circuited. Moreover, the noise level referred to the amplifier input must, in the absence of interference, approach the value determined by the noise resistance of the tube under test. The amplifier is provided for checking tubes of various types with several screened input stages, each of which is wired to the required circuit.



The amplifier is set each time, for measuring batches of tubes of the same type, to a given sensitivity and, depending on the noise level and the required sensitivity of measurements, it can operate either in a wide-band or tuned condition.

Mechanical resonances in the electron tube produced by acoustical vibrations are found by varying the oscillator frequency over the required range. The presence and level of resonance vibrations is then determined either by means of the millivoltmeter or the oscilloscope.

The above method makes it possible to evaluate the structure and manufacturing technology of the electron tube from the point of view of microphonic noise in the acoustical range, as well as the efficiency of its manufacture, to measure the frequency of mechanical resonances in its structure, and to assess the reliability of its operation in the presence of high-frequency vibrations and acoustical interference.

It has been established in testing low-noise 6S4P, 6Zh11P, 6N14P, and 6N3P tubes by means of the above circuit that microphonic noise due to acoustical interference varies over wide limits in different individual tubes. The reproducibility of the measured resonance frequencies and levels of microphonic noise indicates the reliability of the above technique. It became possible by means of the above method to select lamps with a minimum microphonic noise.

HIGH AND ULTRA-HIGH FREQUENCY MEASUREMENTS

APPLICATION OF THERMAL CONVERTERS AND THERMISTORS FOR MEASURING CURRENT IN A MEASURING ANTENNA

V. S. Buzinov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 54-55, December, 1961

Standard methods for checking field-strength meters in the range of 50 to 400 Mc normally comprise standard antennas in the form of half-wave dipoles. It is possible to calculate from a knowledge of the electromotive force ε induced in the antenna and the effective length l_d of the dipole, the field strength at the point where the antenna is situated.

$$E=\frac{\varepsilon}{l_d}. \tag{1}$$

The effective length of a dipole can be calculated with the required accuracy [1, 2] but the value of the emf induced in the antenna has to be measured.

The instrument (voltmeter) used for determining the emf induced in the antenna must measure symmetrical voltages, and its extension probe should be small in order not to distort the measured field. The voltmeter must also have a small temperature error, since measurements are made under field conditions.

A voltmeter with a crystal detector [2] should be the most suitable for measuring the emf induced in an antenna. However, the study of this circuit has revealed that it is unsuitable for the above purpose owing to its low stability, high temperature error, and a considerable sensitivity of its readings to the nonlinear distortion coefficient of the measured voltage.

There exists a method for measuring the emf induced in an antenna by means of a thermistor bridge, which determines the power at the antenna's output. The field strength in this instance is calculated from the formula

$$E=\frac{2\pi}{\lambda}\sqrt{PR_i}, \tag{2}$$

where P is the power measured by the thermistor bridge, w; R_i is the thermistor head input impedance equal to the antenna impedance, ohm; λ is the wave length, m.

The transition from a balanced antenna to an unbalanced thermistor head is accomplished in this instance by means of a tuned screened stub mounted in the immediate proximity of the antenna. Distortions of the field shape, produced by a sufficiently large stub, lead to a systematic error which it is difficult to estimate. There is, in addition, an error due to an imperfect matching of the antenna-feeder-thermistor head circuit. The thermistor bridge can be recommended, owing to the above defects, only for commercial instruments used for measuring the emf induced in an antenna.

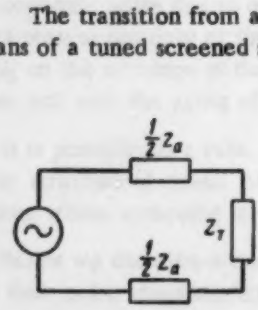


Fig. 1

We recommend that the emf induced in a measuring antenna in the above frequency range should be determined by evaluating the current flowing through the antenna by means of a thermal converter and a milliammeter, and then calculating the emf from the known circuit parameters. In this case the filament of the thermoelement serves as a continuation of the antenna, and the high-frequency current is confined to the system, which is very important for reducing the frequency error of the measuring antenna.

The equivalent circuit of a receiving half-wave dipole with a thermoelement connected to its output is shown in Fig. 1.

An electromagnetic field will produce,in an antenna tuned to the resonant frequency,a current equal to

$$I=\frac{\varepsilon}{Z_a+Z_T}, \tag{3}$$

where I is the current in the antenna, amp; ε is the emf induced in the antenna, v; Z_a is the antenna radiation impedance, ohm; Z_T is the load impedance (of the thermal converter), ohm.

By substituting the emf in (1) by its value deduced from (3) we obtain the field strength at the point where the measured antenna is situated, providing I is measured in the direction of maximum reception

$$E=\frac{I}{l_d}(Z_a+Z_T). \tag{4}$$

Let us now examine the quantities comprising (4).

The effective antenna length l_d is calculated from known formulas [1, 2].

The radiation impedance Z_a of a tuned antenna in free space consisting of an infinitely-thin,ideally-conducting half-wave dipole is equal to 73.1 ohm. For an actual tuned half-wave dipole, Z_a depends on the ratio of the wavelengths to the dipole conductor diameter, and is calculated by means of well-known formulas or evaluated from computation curves [1].

The thermoelement impedance Z_T is determined by measuring the heater resistance R_T with a direct current and calculating the impedance from the known inductance L and the shunting capacitance C. For thermoelements TVB the heater inductance computed from its dimensions is equal to $1.8 \cdot 10^{-8}$ h. Capacitance C, which shunts the heater and is mainly due to the capacitance between the lead-in conductors along the glass,was measured for many thermal converters and found to be equal to 0.6 ± 0.1 $\mu\mu$f. The impedance Z_T of a thermal converter TVB-3, calculated from its parameters R_T, L and C in the frequency range of 150 Mc,differs from resistance R_T measured with a direct current by no more than 0.5%.

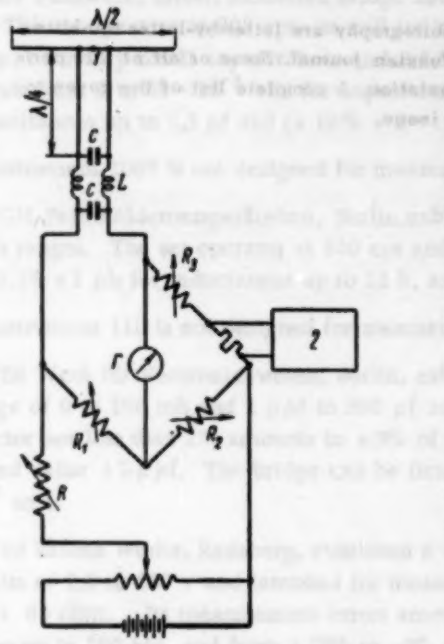


Fig. 2. 1) Thermistor; 2) potentiometer.

Current I is measured directly in the dipole by means of the thermal converter which is calibrated by applying frequency corrections to its dc graduation. The value of these corrections depends not only on frequency, but also on the type of the thermal converter.

We suggest a method for determining the frequency error by comparing the currents measured in identical antennas by means of a thermal converter and a thermistor. The frequency error of a thermal converter is evaluated by alternately measuring by either antenna the same electromagnetic field produced by an auxiliary stable oscillator.

The method of connecting the thermistor and the bridge for measuring the antenna current is shown in Fig. 2.

The quarter-wave line which is shorted by capacitance C and connects the thermistor to the measuring circuit consists of an insulator and does not affect the error of measurement.

The method of evaluating the current in a measuring antenna by means of a thermistor produced very good results. Thus, a tenfold measurement of the antenna current in the range up to 400 Mc produced a quadratic mean error of $\sigma \leq 1.0\%$.

The absence of thermistor frequency errors [4] in the above frequency range and the small quadratic mean error in measuring the antenna current make it possible to adopt this method for initial evaluation of frequency corrections in thermal converters, and for calibrating and checking measuring antennas under laboratory conditions.

The frequency error of a thermal converter TVB-3 operating in conjunction with a measuring dipole antenna was determined by the above method and found to rise monotonically, attaining at 400 Mc a value not exceeding 5%. This error is systematic and can be eliminated.

With a dc calibration error of the thermal converter amounting to ±1.5% and an uneliminated frequency error of ±3% the antenna current can be measured by means of a thermoelement TVB-3 over the whole frequency range up to 400 Mc with an error not exceeding ±3.5%.

CONCLUSIONS

The small error in measuring the antenna current by means of a thermal converter, the possibility of reading this current directly on a pointer instrument, and the small effect produced by ambient temperature on the readings (1% for 10°C) provide the possibility of using a dipole antenna with a thermal converter for calibrating and checking field-strength meters.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

INFORMATION

GDR EXHIBITION OF MONITORING, MEASURING, AND CONTROL EQUIPMENT

M. Kh. Shliomovich and M. Sh. Kapnik

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 56-57, December, 1961

An exhibition of monitoring, measuring and control equipment produced in the GDR (German Democratic Republic) was held at the Polytechnical Museum in Moscow from August 22 to September 10, 1961. Over 30 concerns showed more than 320 exhibits.

Below we give brief technical characteristics of some of the exhibits.

The FEB Funkwerk, Dresden, exhibited a frequency meter FZI-2 which provides frequency measurements in the range of $1-10^5$ cps with an error not exceeding ±3% of the appropriate full-scale deflection when its input is fed with a voltage of 0.5 to 50 v. Frequency meter FZ103 of the same concern has a range of $1-3 \cdot 10^5$ cps and is a more sensitive instrument. Its error does not exceed ±2% of the appropriate full-scale deflection when its input is fed with a voltage between 0.1-25 v.

FEB Funkwerk, Erfurt, exhibited bridge 1007 for measuring capacitances of 0.01 $\mu\mu$f to 10 μf in 6 measuring bands. The set operates at 800 cps, its null indicator consists of a telephone, its measurement error does not exceed ± 0.01 $\mu\mu$f for very small capacitances and ± 0.7% for relatively large capacitances. The measurement range of tan δ extends from 0 to $50 \cdot 10^{-3}$ and for capacitances up to 100 $\mu\mu$f and more. Its measurement error is $(\pm 10\% + 1 \cdot 10^{-3})$ for capacitances up to 0.1 μf and $(\pm 10\% + 2 \cdot 10^{-3})$ for capacitances over 0.1 μf.

Instrument 1007 is not designed for measuring electrolytic capacitors with a dc polarizing voltage.

PGH Fernmeldemessgerätebau, Berlin, exhibited bridge 110 for measuring inductances between 10 μh and 110 h in seven ranges. The set operates at 800 cps and uses a telephone as an indicator; its measurement error does not exceed ± 0.1% ± 1 μh for inductances up to 11 h, and ± 0.5% in the measurement range of 10 to 110 h.

Instrument 110 is not designed for measuring iron-cored inductances with a dc current flowing through them.

FEB Werk für Vernmeldewesen, Berlin, exhibited bridge LCM1 for measuring inductance and capacitance in the range of 0 to 100 mh and 1 $\mu\mu$f to 300 μf at a frequency of 500 kc; the measurement error for inductances (with a Q-factor not less than 10) amounts to ± 3% of the measured value $\pm 20 \cdot 10^{-9}$ h, and for capacitances, ± 3% of the measured value ± 2 $\mu\mu$f. The bridge can be fitted with an attachment TLG1 for measuring tan δ in the range of $1 \cdot 10^{-3}$ to 1.

FEB Rafena Werke, Radeberg, exhibited a voltmeter DVM107, working in the decimeter band on six ranges with top limits of 2.5 to 250 v and intended for measuring in the range of 10^{-3} to 1000 Mc. The impedance of the instrument is 60 ohm. Its measurement errors amount to ± 10% to -2% of the appropriate full-scale deflection at frequencies up to 300 Mc, and from + 28% to -2% at frequencies up to 1000 Mc.

The FEB Funkwerk, Erfurt, exhibited two new sets for rapid checking of transistors and crystal diodes. Set type 1019 is intended for measuring the collector reverse current and current amplification in common emitter circuits in the range of h_{21} from 9 to 200. Set type 1200 is designed for measuring the collector reverse current and signal amplification by power transistors in the amplification range of 16 to 200.

The same concern exhibited an ultrasonic flaw detector type 9024 with a relatively small ultrasonic absorption, for detecting faults in materials and complete metal, ceramic or plastic articles, without damaging them. The instrument is fitted with transducers (probes) of different design and provides measurements by means of its six ranges at depths from 5 mm to 5 m. The pulses which are converted by the instrument are displayed on a screen of a cathode-ray tube and can be photographed by a camera attached to the instrument.

FEB Transformatoren und Rentgen Werk exhibited a portable gamma-ray flaw detector type TfIR MIr16, which has a lead shield 7.3 cm thick and is intended for checking welded joints, light metal alloy castings, and steel articles 10 to 50 mm thick. The instrument uses as a radioactive element Ir^{192} (10.5 radium equivalents) or Cs^{137}. The instrument is fitted with two-meter long remote control rods.

FEB Gerätewerk, Karl-Marx-Stadt, exhibited a fluxmeter with a luminous scale for measuring magnetic flux (or magnetic field strength) up to 10 mv · sec (10^6 Mx). The instrument's error does not exceed ±1.5% of the full-scale deflection with an external resistance (resistor with connecting leads) not greater than 100 ohm.

FEB Wek für Fernmeldewesen, Berlin, exhibited rectangular wave voltage generators types RWG-2 and RWG-4, with a frequency range of 50 to $5 \cdot 10^5$ cps and a frequency setting error of ±10%. In generator RWG-2 the pulse rise time does not exceed 0.1 μsec; the slant of the pulse top does not exceed 2% with a load impedance not less than $10^7/f$ ohm (f is the frequency in cps). Its output voltage amounts to 0.1 to 3 v max across a load resistance of 10^4 ohm (with an error of ±20% ±0.1 v max). Its pulse duty factor is 1 : 1 with an error of ±10%.

The FEB Funkwerk, Dresden, exhibited an interference detector Stg_4 with eight ranges covering frequencies from 30 to 230 Mc. The instrument's sensitivity is 1 μv for frequencies up to 150 Mc and 2 μv for higher frequencies; its frequency measurement error does not exceed ±1%.

A clock-pulse generator TS 1-8 was exhibited by the FEB Funkwerk, Kopenik. It is used mainly in pulse techniques for connecting instruments which do not possess their own starting element. The starting condition can either be internal or external. The pulse sequence for internal starting is controlled continuously in the range of 10 to $2 \cdot 10^5$ cps. The starting condition for a sinusoidal voltage is $\geq 4\ v_{eff}$, and for positive and negative pulses it is $\geq 15\ v_{max}$. The generator has two inputs, one for a direct and the other for a lagged pulse sequence. Its internal impedance is 150 and 600 ohm, its output voltage amounts to 40 and 50 v_{max}, respectively. The same concern exhibited a pulse amplifier type IV-10 for amplifying periodic and nonperiodic ac voltages in a range of 5 cps to 7 Mc with a continuously adjustable gain. Its maximum input voltage is 5 v_{eff}. It has an input resistance of 1 meg, an input capacitance of 22 μμf, and a maximum gain of 1000. The instrument operates from 50 cps mains.

In addition to the above, many other different measuring and controlling instruments and devices were shown at the exhibition. They included instruments of considerable interest such as recording electronic compensation instruments for measuring, recording and controlling temperature and other physical parameters which can be converted into electrical quantities, devices for controlling levels, electrical conductance, quantities of liquids and other values, a pneumatic low-pressure computing system designed for teaching technical personnel and schoolchildren, devices for testing manometers, program regulators, and other instruments and installations intended for various branches of industry.

ANALYTICAL BALANCES ON ELASTIC (STRIP) SUSPENSIONS

Translated from Izmeritel'naya Tekhnika, No. 12,
p. 57, December, 1961

A single-pan 200 g analytical balance type Vivensil-357 was shown by the Adamel firm at the French exhibition in Moscow in 1961. The beam of this balance has one arm only, from which a pan is suspended with a total mass of weights of 200 g.

The weighing on this balance is done according to D. I. Mendeleev's method, which consists of evaluating the mass of the body placed on the pan by the amount of weights removed from the beam.

The weights are removed by means of levers extended to the front panel of the balance. The total value of the gram and milligram weights thus removed is automatically transmitted to a digital scale in the center of this panel. Fractions of a milligram are read off a moving optical scale placed at the eye level in the upper part of the panel.

The peculiarities of the balance are the following:

a) The beam is suspended from the support on two thin and flexible strips made of a special alloy of the type of beryllium bronze;

b) the pan is suspended from the beam on similar strips;

c) the balance has no arrest;

d) the balance is fitted with a locking device for securing the beam and the pan in transportation.

The advantages of the Vivensil-357 balance consist of the absence of knife edges and blocks, thus greatly extending the period between repairs as compared with knife-edge balances, of higher precision due to the absence of unequal arms, of greater stability in readings than in knife-edge balances due to the elimination of the arrest and absence of friction which is inevitable in balances with knife edges, of constant sensitivity due to the fact that in a balanced condition the beam always remains in the same position, of a convenient indicating device, and, finally, of the ease with which it can be transported.

The technical characteristics of the balance are:

Maximum load, g	200
Multiplying factor, mg	0.1
Free space above the pan, mm	170
Diameter of pan, mm	80
Distance between the suspension axes of the pan, mm	98
Over-all dimensions (length × width along the face × height), mm	521 × 281 × 524
Weight, kg.	20

METHOD FOR AUTOMATIC AND ACCELERATED TESTING OF MOISTURE CONTENT IN SOLID FUELS

B. M. Ravich

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 57-60, December, 1961

The existing methods of determining the moisture content in solid fuels based on the use of a drying ovens or the treatment of the tested fuel with cold acid, magnesium methyl iodate, calcium carbide, aluminum sulphide, aluminum chloride, etc., do not provide a rapid checking of moisture.

Hence,the work for finding rapid and accurate methods of measuring the moisture content in solid fuel is receiving serious consideration.

The greatest attention is attracted by methods based on the use of infrared radiations for drying samples of the tested material. The application of infrared radiation for determining rapidly the moisture content in solid fuel [1, 2, 3, etc.] has been studied at the KuzNIUI (the Kuznetsk Scientific Research Institute of Coal Preparation), showing that these methods have as yet been insufficiently mechanized and therefore can only be used, in the main, for analytical work under laboratory conditions.

An advance in the automation of these installations has been made in the instruments designed by the automation laboratory of the NIIU (Scientific Research Institute of Coal Preparation). A portable set I-5-P-2 and a semi-automatic installation I-6 are now being produced. The weighed portion of coal rotates in these devices, and the two-stage drying is made automatic with respect to temperature and time. The temperature of coal in the first radiation drying amounts to 140-150°C, and in the second period it is at first lowered to 110°C and at the end of the period again raised to 140-160°C, which is followed by an automatic switching off the bulbs. For brown coal the complete radiation cycle at a distance of 45-50 mm from the center of the bulb to the scale pan amounts to 4-7 min. The difference in the measuring results obtained by this method and by the standard method does not exceed ±0.3%, which is completely satisfactory for production conditions.

The device for a rapid evaluation of the moisture content developed by K. N. Chizhova is distinguished by its simplicity. It consists of two massive metallic plates hinged to each other for the purpose of setting the distance between them. The plates are heated by means of flat electric heaters placed on the outer side of the plates. Cylindrical sockets are drilled in the plates for thermocouples which are used for measuring the temperature of the heating surfaces. The weighed portion of the analyzed coal which is placed between the plates amounts to 5 g. The duration of dehydration and drying varies,according to the properties of the material and the initial moisture content, from 3 to 8 min. The moisture evaluation by this method approaches that of a standard method. However, the instrument has several structural defects and cannot be recommended for general use.

The Leningrad Polytechnical Institute has developed an instrument for the rapid determination of the humidity of peat [4]. The instrument consists of a transducer connected to an RC circuit, a pointer galvanometer and a storage battery. Two types of transducers are made, one consisting of a net and the other of a probe, for determining the moisture content with and without sampling,respectively. A large number of series-connected thermocouples (several hundred) have a negligibly small thermal capacity, but make the transducer extremely sensitive and determine with great accuracy the speed with which the net heats up. The error in determining the moisture content of peat amounts, according to available data, to ±0.5%. It is possible that the above instrument could be used for rapid measurements of moisture content in coal which has a stable composition with respect to the quantity and quality of cinders. However, the complexity of the instrument,due to the large number of thermocouples,restricts its application under production conditions.

The principle of measuring the characteristics of materials in a high-frequency electric field are being applied, for instance, in hygrometer VÉB, which is provided with a simple and accurate resonance circuit based on the "choking of oscillations." The principal part of this circuit consists of a tube oscillator with a quartz crystal stabilizer.

A further improvement and simplification of the oscillation choking circuit was attained by using tube 6E5S as an electronic indicator of tuning. The triode part of the tube is used as a stabilized oscillator with a quartz crystal (f = 1.45 Mc) between the cathode and the grid. A resonance circuit containing a capacitive transducer is connected to its anode circuit. A large resistance in series with the tuned circuit is connected between the anode and the screen of tube 6E5S. A sharp reduction in the anode current at the instant the oscillations start decreases the voltage drop across the resistor between the control grid and the screen, thus greatly diminishing the dark sector on the screen, etc. The combination of voltage and frequency stabilization makes the hygrometer readings independent of supply voltage variations over a very wide range (90-230 v). The measuring range in terms of capacitance units amounts to 25 $\mu\mu f$, and the maximum error in measuring capacitance does not exceed 0.2 $\mu\mu f$ [5]. Hygrometer VĚB was employed in the Moscow coalfield for determining the moisture content of coal dust used in thermal electric power stations. According to the data given in [5] this hygrometer can be used without alterations of its measuring unit for evaluating the moisture content of coal dust in the range of 4 to 23-24%. Higher values of moisture content can be measured by connecting in series with the instrument transducer a constant capacitance compensator. It is recommended to compile conversion tables for various grades of coal (or groups of grades) when the hygrometer is used for speedy evaluations of the moisture content.

The Institute of Giprougleavtomatizatsiya (State Institute for the Planning and Design of Coal Automation Equipment) has developed capacitive hygrometers AVU-1 and AVU-2, with transducers consisting of porcelain beakers. When the transducer is filled with air its capacitance is at the minimum; when it is filled with dry coal it is 3.8, etc. The transducer is heated in order to avoid wet coal adhering to its sides. The Institute is now improving the instrument in order to obtain more stable results for various grades of brown coal [6].

A hygrometer for continuous checking of the moisture content in coal furnace charges has been installed at the Voroshilovgrad coke and chemical plant [7]. A voltage of 60-100 v is connected from a transformer across coal charges travelling on a conveyor. The secondary winding of this transformer is coupled through a selenium rectifier to an indicating instrument with a scale calibrated in percentage of humidity content. The electrodes are placed 500 mm apart at a height of 25 mm above the conveyor belt. The equipment is switched from one belt to the next every 15 min. Extensive check testing has shown that the error of the instrument in measuring humidity content does not exceed ±0.4%. This hygrometer is undoubtedly of considerable interest for testing before coking the humidity content of coal (concentrates) with a small percentage of cinders.

Other original instruments have been developed in the Soviet Union for checking the humidity content in solid fuel such as the VUKhINA set 2IL-1, the Zaporozh'e coke and chemical plant hygrometer, etc. [8, 9, 10].

Radmacher's (FRG) is one of the methods based on the operation of various chemical reagents, and consists of determining the quantity of moisture contained in a sample by the reduction in the specific gravity of a salt solution which absorbs that moisture. The water-vapor pressure in a zinc chloride solution is lowered by adding to it lithium chloride, since virtually the whole moisture is absorbed by the salt solution. The reduction in specific gravity is determined by means of an areometer and serves as a measure of the moisture content, since no other coal components dissolve in appreciable quantities. The salt solution concentration equalizes in coal easier than in coke, since the coke has a fine porosity which impedes the penetration of the solution. The time required for the treatment of coke can be reduced by 20 min if it is crushed to a size of 5 mm and the air in its pores is extracted by means of suction. The data obtained by the lixiviation method coincide with those of the drying method. This method can be recommended in the case when the analysis must be made at the place where the sample is taken [11].

A method of rapid determination of the humidity content developed by Fischer as early as 1935 is widely used abroad. At present it is the most commonly used of all other methods in which the moisture content is determined by means of chemical reaction [12].

The standard method used in Spain for determining moisture content of solid fuel consists of distillation with toluene or xylene.

The firm Ridel de Hein (FRG) produces equipment for rapid determination of the moisture content in coal by the gasometric method [13]. The reaction of calcium carbide with water produces acetylene gas in such a manner that the moisture content corresponds to a definite (proportional) pressure of acetylene. Thus it becomes possible to judge the moisture content of the tested sample of coal for definite weighed portions of coal and calcium carbide by the pressure of acetylene. The method can be used under production conditions without a special chemical laboratory. The error in determining the humidity content is large and reaches ±3%.

A method based on the difference in the conductance of coal and the water contained in it is described in [14]. The electrical circuit of the instrument is connected to a grounded capacitor between whose plates the coal is propelled. The measuring circuit contains a time relay and recording equipment which provides a remote recording of the humidity content at very short time intervals. No practical data on the speed and accuracy of measurement by means of this method are provided in print.

An instrument for automatic determination of the moisture content of a flow of coal by means of infrared radiations is described in [13]. The coal is placed on a special conveyor belt and dried in an oven equipped with infrared bulbs. After a lapse of time which has previously been determined experimentally as necessary for drying the material (up to a constant weight) it is placed on scales and weighed. The loss in the weight of the material expressed as percentage moisture content is registered by a special indicator and recorded. According to preliminary data of the manufacturing firm, the duration of one measurement does not exceed 7.5 min. A single evaluation of moisture contained in coal can be carried out with a weighed portion up to 400 g.

A method which intensifies the existing techniques for testing moisture consists of the accelerated moisture measurement by means of Brabender's [15] moisture analyzer. The instrument combines a sample drying oven and a scale so that the weighing can be carried out without removing the sample from the oven. The scales are calibrated in such a manner that the percentage content of moisture can be observed on an illuminated scale when a 10 g sample is analyzed. Ten samples can be dried simultaneously on a rotating table in such a manner that the samples reach the weighing position one after the other. The oven is fitted with a ventilator which mixes the hot air, thus intensifying considerably the drying process. According to the printed information, an approximate determination of moisture is obtained in 20-30 min, and an accurate determination in 75 min (for coal samples containing 66% of moisture).

The xylene distillation method is being used fairly widely abroad. This method provides direct measurements with very accurate results. It is used most often for analyzing solid fuels which are sensitive to oxidation in air.

The Nuclear Physics Institute (Czechoslovakia) has designed a neutron hygrometer (probe) for determining moisture in various materials. The action of the instrument is based on the deceleration of neutrons when passing through a medium containing hydrogen, thus producing a linear relation between the number of slow neutrons and the number of hydrogen atoms in the tested sample per unit length of the neutron path [16].

Special vacuum ovens for analyzing moisture are made in Britain. Their principle of operation is similar to that of ordinary drying ovens with the exception that the vacuum accelerates the drying of the solid fuel samples [17].

The so-called extraction method of determining moisture in dispersed and powdered materials is being used increasingly in recent years in a number of countries. The method is based on measuring the conductivity of extracts. Among the different techniques of applying this method the one that deserves the greatest attention consists of extracting moisture from the salts of NH_4NO_3 and NaCl by means of 1.4-dioxane and methanol solutions with subsequent measurements of the extract characteristics by a "nonelectrode" capacitive transducer at a frequency of 9.45 Mc. The above method has not been used for measuring the moisture of solid fuels. However, it is possible to assume that for thinly dispersed solid fuel fractions with close chemical characteristics this method can be applied.

CONCLUSIONS

The majority of the above methods suffer from serious defects. The preparation of average samples (selection, separation, crushing, etc.) is very labor-consuming, requires much additional time, and makes remote control of moisture in solid fuels impossible. Therefore, such methods are, as it were, transitional to methods of an improved type.

The method of infrared radiation (for instance, of the Scientific Research Institute for Coal Preparation) will undoubtedly find a wide application providing its automation is extended.

It should be noted that methods of measuring the electrical characteristics of fuel which form the basis for automatic remote control systems for measuring moisture encounter considerable difficulties in connection with the nonuniformity of fuel used in production. In this connection the method of automatic moisture measurement in flows of the material deserves particular attention.

The work in producing methods and equipment for automatically checking moisture in solid fuels must be considerably extended, since various branches of industry are in urgent need of such equipment.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**

MATERIAL RECEIVED BY THE EDITORIAL BOARD

CENTRALIZATION OF TEST LABORATORIES IN PLANTS

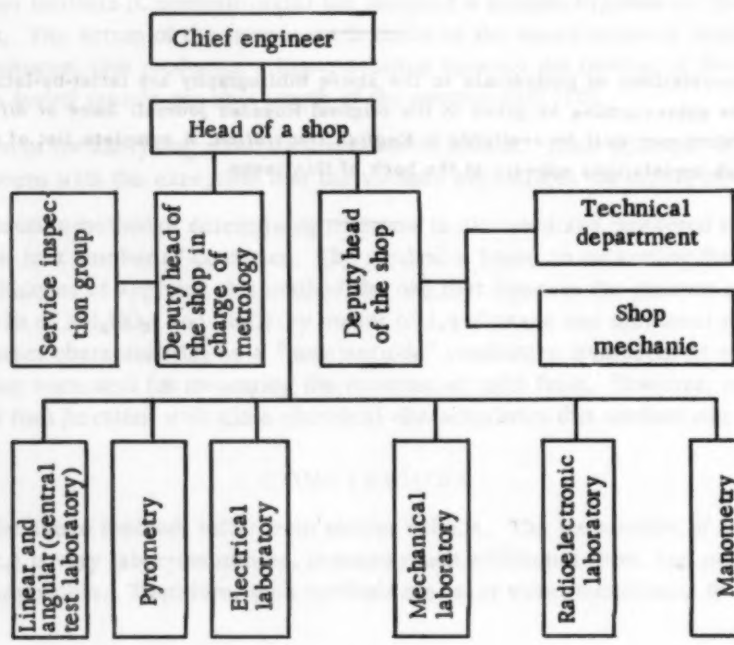
E. A. Simson

Translated from Izmeritel'naya Tekhnika, No. 12,
pp. 60-61, December, 1961

The technical progress of our country requires the further development and improvement of measurement techniques. An important part in this task should be played by factory test laboratories. They must ensure the uniform, accurate and correct use of measures and measuring instruments, and also actively participate with the plant's technological agencies in assimilating new measurement equipment and improving the technology of production.

One factor impeding the activity of factory test laboratories consists of the existing organizational form. In the majority of plants the test laboratories are subordinated to various workshops and departments. Such isolated laboratories are overwhelmed by the tasks facing them and, therefore, one of the most pressing problems for the inspection personnel consists, at present, of the rational and efficient organization of test laboratories at the plants.

The administration of our plant could not decide on the manner of unifying the existing test laboratories immediately on receipt of a copy of the "Model Instruction on the central measuring equipment laboratories at plants," approved by the Committee of Standards, Measures and Measuring Instruments attached to the USSR Council of Ministers.



At a conference to which the representatives of all the interested services were invited, it became clear that complete chaos reigned in the approach to this problem.

Some shop foremen resisted unification from the point of view of "feudal lords." Others, on the contrary, wanted to get rid of the "burden" and did not oppose the unification of laboratories.

This narrow approach prevented us from reaching a unanimous decision. The "Model Instruction on central measuring equipment laboratories in plants" is being forced upon us by life itself. However, the Sovnarkhoz (Council of National Economy) is not helping us to adopt it. The personnel of the standardization, normalization and

measuring technique department of the Sovnarkhoz state that the Sovnarkhoz cannot issue an instruction for a compulsory centralization of test laboratories at the plants, since the "Model Instruction on CMEL" is not a dogma. The only assistance rendered by them consists in suggesting, in the documents on the inspection of the measuring equipment, that the laboratories should be unified. The chief engineer passes this document to the service inspection chief of the plant who simply allocates it to an appropriate file.

The state inspection laboratories of measuring equipment pay considerable attention to this problem, but their rights are strictly limited.

One of the obstacles to the centralization of test laboratories also consists of their territorial dispersion, yet it is impossible to erect a separate building without prohibitive financial allocations.

The plant administration pays little attention to the inspection department problems. The supply of test equipment and spare parts is unsatisfactory. Owing to the absence of unified leadership and control over the work of test laboratories and their subordination to various departments of the plant, they perform unsuitable work; for instance, the electrical laboratory is engaged in testing protection gear (mats, gloves, etc.) and adjusting relay safety devices. Similar distribution of work occurs in other laboratories.

In our plant there are nine inspection agencies which we have decided to amalgamate.

We proposed the following structure for a "measurement equipment shop," responsible directly to the chief engineer (see Figure).

It was proposed to staff the shop by available workers, engineers, technicians and office workers according to existing plans.

The amalgamation of the laboratories will make available several reference instruments and a large production floor-space, but this question has remained unsolved for several months.

A similar condition exists in the plants of Moscow, Kuibyshev and Ufa, which the author of this article has had the opportunity of visiting.

It is necessary to examine this important question with respect to each plant. Thus, where necessary, measuring equipment shops or departments should be established.

It should be desirable for the readers of "Izmeritel'naya tekhnika" to express their opinion in this journal, and for the workers in the plants where central measuring equipment laboratories have been organized to share their experience.

CERTAIN PROBLEMS IN THE OPERATION OF THE GKLs (STATE INSPECTION LABORATORIES)

Yu. A. Cherkasov

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p. 62, December, 1961

The Seven-year Plan for the development of the USSR National Economy and the new program of the CPSU (Communist Party of the Soviet Union) open up wide prospects for the active participation of the public in the solution of many problems.

Experts in many branches of our industry could, on the basis of social work, render considerable assistance to the GKLs in many spheres of their activity. Such spheres include, in the first instance, the enforcement of state standards, the assimilation of new measuring equipment by our national economy, as well as the finding and withdrawing from use of obsolete equipment which does not meet modern requirements. The assistance of a public organiza-

tion consisting of leading production workers, engineers and technicians, active Komsomols (members of the Young Communist League) and pensioners, working under the guidance of the GKL, would undoubtedly make this work more efficient.

It is a fact that the polytechnical organization of schools brings them closer to production. It is necessary to organize, with the assistance of the GKLs, the training in secondary schools of inspection workers, such as inspectors for the inspection and test departments, laboratory workers for central test laboratories, specialists in repairing measures and measuring instruments. These people could continue their education in appropriate technical schools and metrological faculties of higher technical educational establishments. The GKL personnel should have close relations with schools where such groups of future metrological workers exist by giving them talks, lectures and lessons, and by providing practical experience for these scholars in their laboratories.

At present a considerable number of GKL workers lack an appropriate metrological qualification. Such workers are not allocated for a considerable time any independent inspection work and are not supplied with inspection stamps.

We cannot consider such a state to be normal. The question arises, why should this have happened? Why do not the heads of the GKLs encourage their workers to sit for external examinations and receive qualifications of a state inspector? This is because it would take the workers away from their routine occupations and impede the fulfillment of the plan, since with the small staff of the GKLs literally every man counts. Moreover, preparations for examinations in special subjects which have to be taken according to a curriculum can only be carried out in the spare time outside working hours, which for various reasons is not possible for everyone.

In our opinion the way out of this predicament consists of organizing examinations at the GKLs. Each laboratory has a sufficient number of qualified workers with large practical experience who could become members of examination boards. Such an arrangement would save travelling expenses and time of the laboratory personnel. It is possible to organize examinations simultaneously for several GKLs, which are located near to each other. It is also timely to consider resuming the courses for state inspectors, since they provide the possibility of preparing skilled experts. It would also be a good idea to introduce badges for state inspectors and senior state inspectors, which would serve as a spur for the GKLs workers who have no metrological qualifications.

ORGANIZING THE PRODUCTION OF AIR CONDITIONING EQUIPMENT

M. E. Galkin

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Measures and measuring instruments must be checked and used under strictly observed temperature conditions specified by GOST (All-Union State Standard) 9249-59 and Instruction 100-60 of the Committee of Standards, Measures and Measuring Instruments.

In order to preserve these conditions the premises of test laboratories must be equipped with air conditioning installations or heat-controlling devices.

Air conditioning is of great practical value for production premises as well, since it would lead to a considerable rise in the accuracy of the manufactured components, ensure high quality of production, and provide healthier working conditions for the personnel, which in turn will lead to a rise in labor productivity.

However, the heads of establishments and planning organizations neglect this question. No model projects or installations for compact and inexpensive temperature-control devices have been developed.

The Councils of National Economy should tackle the question of air conditioning in their plants, and the Representative of the Committee of Standards, Measures and Measuring Instruments should assist the councils and their plants in providing the factory laboratories with temperature-controlling equipment.

APPLICATION OF LIGHT FILTERS TO OSCILLOSCOPES

Yu. A. Magnitskii

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p. 63, December, 1961

In the existing moving-coil loop oscillographs all the tested processes or quantities are produced on the screen or moving picture film in a single color. This fact makes it difficult to distinguish between curves and decipher them, especially if they are similar (for instance, in a simultaneous study of pressure variations in several cylinders of an internal combustion engine).

The Rostov Institute of Railroad Transport Engineers has developed a method of obtaining color images on the screen and moving-picture film by means of light filters of different colors.

Each light filter is placed in the luminous path of the appropriate vibrator. It is most convenient to place the light filters in the openings of the oscillograph casing partition.

The light filters must be made from plane-parallel glass and possess a low optical density. They should have frames made of thick foil and clamps for fixing in the partition.

LEVELING STRAIGHTEDGE OF A NEW CONSTRUCTION

N. G. Klyuchnikov

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p. 63, December, 1961

The Central Test Laboratory of the Élektrostal' Heavy Engineering Plant has developed a metal straightedge with a moving frame by which the height of one point with respect to another is determined in leveling operations during the installation of metal constructions.

The moving frame has three similar scales which differ from each other by the width of their calibration lines (0.3, 1, and 2 mm). Each of these scales is intended for working at an appropriate distance of the leveling instrument from the straightedge.

The frame is secured in the required position on the straightedge, which is fitted with a plumb line and an illuminating bulb from a pocket flashlight.

The above device provides a high accuracy and ease of operation as compared with wooden straightedges which are used in geodetic operations.

The maximum level differences it can measure amount to ± 60 mm.

METAL PEDESTALS FOR MANOMETERS

G. V. Savchenko

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p. 63, December, 1961

Welded metal structures are used as pedestals for supporting weighted-piston manometers. The framework is made of 60 × 60 mm angle iron, and the side walls of 2 mm sheet iron. The thickness of its cover amounts to 8mm, and of its door, to 4 mm.

The dimensions of the pedestal were selected to suit the size of the weighted-piston press and provide convenient operation. They amount to a length of 650 mm, a width of 650 mm and a height of 870 mm.

The weighted-piston manometer is stably fixed to the pedestal by special set screws. The weighted-piston press type PG-2500 is mounted on two pedestals.

The front door of the pedestal is hinged to the casing on special brackets. Shelves for storing accessories are fitted inside the pedestal (connecting pipes, keys, ground points, etc.).

The structure of the pedestals provides the operator who is checking a manometer with a convenient position on any side of it, thus raising the efficiency of his work.

The metal pedestals last longer than wooden pedestals and have a pleasing appearance. The pedestal framework and cover are polished, and the side walls and door are covered with an oil paint.

Other instruments, for instance, a mercury-piston vacuum meter, can also be mounted on the pedestal. This makes the work of the tester much more convenient.

Such metal pedestals designed by the author in 1956 are now being made and successfully used in the Ternopol' State Inspection Laboratory of measurement equipment.

Similar metal pedestals have been made by a number of plants in the region for their weighted-piston presses.

The cost of a pedestal is 43 roubles.

REVIEWS

TECHNIQUES FOR MEASURING MASS (by S. S. Shchedrovitskii)

P. N. Agaletskii

Standartgiz, Moscow (1961)
Translated from Izmeritel'naya Tekhnika, No. 12,
p. 64, December, 1961

The book under review consists of four parts.

The first part is entitled "Scales and Weights. General Characteristics," and provides a classification of scales and weights, indicating the sphere of application of scales based on different principles of operation. It should be noted that the same author, in an article published in the journal "Priborostroenie," No. 12, 1960, provides a more exact classification of scales as compared with that given in the book. The first part concludes by indicating the principles and tendencies in standardizing scales used for different purposes.

The problems of standardization, normalizing characteristics, and evaluating the prospective development of weighing equipment production form the backbone of S. S. Shchedrovitskii's book. Greater attention should have been paid by the author to standardization techniques.

The second part of the book deals with "Weights." It consists of four chapters, namely, "Single System for Grading Weights," "Design of Weights," "Errors in Using Weights," and "Special Weights." The book indicates the need for and the possibility of replacing the multiplicity of reference and working weights by a restricted number of grades which form a single system based on rational principles. While the book was being produced a standard has been drafted which, to a great extent, reflects the above suggestions.

The book cites interesting data regarding the design of weights for various grades of accuracy. The suggestion of standardizing tolerances in weights which are in use on the basis of the conditions of their application should be specifically noted. Such an approach to the question, in our opinion, is fully justified.

The section dealing with estimating errors due to aerostatic forces also deserves attention.

In the chapter entitled "Special Weights" the author describes weights exceeding 20 kg and deals in detail with the technique developed by him for calibrating small weights on torsion balances.

The whole section on "Weights" represents a complete monograph.

The third part of the book dealing with laboratory balances has also a monographic nature. The author produces a considerable amount of new data on the design of laboratory balance components, including electronic attachments which serve for remote transmission and recording of balance readings, as well as for automation of weighing. He describes analytical balances and general laboratory balances, provides a review of the most interesting and promising designs, determines the trends of future developments, provides and analyzes metrological requirements for these developments, and notes the propositions which could serve as a basis for drafting standardization documents.

The chapters dealing with ultramicrobalances and laboratory balances for special applications contain a number of designs for balances, including electronic balances; however, they are in the main of a descriptive nature.

The author should be reproached for not quoting, when he deals with articulated joints in laboratory balances, the results of investigations of knife-edge and block systems carried out by the VNIIM (All-Union Scientific Research Institute of Metrology) in connection with the improvement of reversing pendulums. These investigations have shown the part played by the conserving and dissipating forces, and the moments produced by them in the operation of the articulated straightedge and block bearing.

The last section, entitled "Automatic Balances," consists of seven chapters. In the chapter dealing with components of automatic balances the standardization data have been partly classified for hoisting devices, dial heads, knife-

edges and other components. The chapter also deals with devices for automatic balancing, remote transmission and recording of readings, and with transducers used in automatic balances. The author should have dealt in greater detail with the application of electrical strain-gauge elements and given a description not only of the simplest designs and circuits for such elements, but also of special types of strain-gauge transducers for balances (for instance, of the toroidal type), and various measuring circuits, including those used for operation with several transducers. The book does not describe with sufficient detail scales with automatic balancing; suffice it to say that the author has not described a single design for spring balances or other widely used devices with elastic elements.

The main defect of the chapters dealing with automatic batching scales, dosage machines, automatic balances, continuously operating dosage machines and automatic weight-checking machines is that they only contain descriptions of various types and designs of weighing instruments, and the author's appeals for unification of designs and standardization of characteristics are not supported by sufficiently specific technical suggestions. At the same time it should be noted that many descriptions of scales are of interest and will be useful to the reader. This is particularly the case with various types of "dynamic" scales which provide weighing during the transportation of the load.

The most serious shortcoming of the book, in our opinion, consists of the lack of a section dealing with ordinary, nonautomatic scales. In the foreword the author justifies this by suggesting that automatic scales are the most promising for the future. However, in a book which gives its main attention to the normalization and standardization of characteristics, the most commonly used scales should be placed in the forefront.

It is annoying that the author did not pay sufficient attention to rigorous formulation and at times presents his material in a slipshod style, borrowed from journalism. The laconic description of certain designs makes it difficult to understand them.

However, the basic aim of the author, to show the trends in the development of weighing-equipment construction and the technique for designing rational sets of weights and scales, has been attained by him, despite the shortcomings noted above. This book will be useful not only for weighing-equipment manufacturers, but also for designers, investigators and experts who use weighing methods for checking and automation of technological processes.

FROM FOREIGN JOURNALS

INSTRUMENTS AND CONTROL SYSTEMS

No. 4, April 1961

P. Odham. Equation for the rate of flow measured by a differential manometer.

K. Bowers and others. Measurement of flow rates in rocket techniques.

J. Powell. Variable area flowmeter for bubbling lines. Measurement of flow rates of water from 0.04 to 150 liter/hr and of air from 0.003 to 3.3 nm^3/hr.

D. Laub. Thermal flowmeter.

D. Robertson and F. Shuster. Flowmeter with a velocity head tube.

L. Polentz. Caplastometer.

ARCHIV FÜR TECHNISCHES MESSEN

No. 302, March

H. Jan and E. Lorentz. Automatic digital bridge for measuring resistances.

K. Müller. Vacuum measurement technique. Methods for discovering leaks, controlling, regulating and automating vacuum installations in production are also described.

G. Schwarz. Methods and instruments for measuring small gas pressures, part VII. Ionization manometers. Measurement range down to 10^{-10} mm Hg.

No. 303, April

O. Felker and W. Zengl. Measurement of peak values in large ac voltages.

P. Menzel. Measurements in nonuniform magnetic fields by means of transducers based on the Hall effect.

G. Zieher. Determination of separate component errors in gears.

K. Sattelberg. Measurements of frequency and phase. Review of literature.

No. 304, May

W. Zotmann. Accurate weighing of loads by measuring the sagging of a rail.

G. Müller. Measurement of temperature by means of optical pyrometers.

W. Meskat. Development trends in viscosimetry.

G. Heuer. Measurement of small loss angles in capacitors.

P. Wunderer. Measuring amplifiers.

MESURES & CONTROLE INDUSTRIEL

No. 291, 1961

"Mesucora 1961" Exhibition (continuation)

No. 292

M. Danlux-Dumesnils. From the Florentine to the Lyons thermometer. Historical essay on the origin of thermometers.

M. Jacob. Application in metrology of the mathematical principle of difference calculations.

METROLOGIA APLICATA

No. 1, 1961, January-March

V. Gabrielescu. Protection of measuring instruments from external shocks. Special systems with one degree of freedom.

M. Belesescu. Laboratory goniometers.

F. Drujnitki and G. Ispesoiu. Evaluation of errors in calibrating temperature standards in the Rumanian People's Republic.

V. Cristescu. Reference standard cells.

F. Veres. Application of radioactive isotopes in measurement techniques.

No. 2, April-June

R. Sentilic. Control and measurements are the basic elements in raising the quality of production.

G. Ivanovic. From the history of Rumanian metrology.

O. Vetesan. Modern tolerances for gauges.

G. Eliade. Correct utilization of tolerance fields in modern equipment.

R. Precsl. The effect of instrument deformations on determining hardness by the Rockwell method.

G. Ispesoiu. Extrapolation of the International Temperature Scale above the solidification point of gold.

V. Cristescu. Variations in the construction of Weston cells.

M. Birjena. Checking the quality of depolarizers in Weston cells.

I. Cepoi. Organizing an internal inspection of the measurement equipment at plants.

E. Dorfman. Principles of supplying industrial concerns with measuring equipment.

No. 3, July-October

G. Ispesoiu. Sectored disk. Its application in extrapolating the practical temperature scale above the solidification point of gold.

V. Petrescu. Weighted-piston manometer.

E. Verzaru. Application of a tungsten-molybdenum thermocouple for measuring fused metal temperatures.

P. Popescu. Measurement of flows by means of diaphragms.

V. Constantinescu. Selecting measuring equipment for use in dosimetry.

VDI ZEITSCHRIFT

No. 12, 1961

G. Bartelt. Problem of installing dynamometers. Spheres of application, including weighing, level measurements, tension in strips during rolling, etc.; design, location, and error of readings.

G. Kreisel. Instrument with a straightedge for checking gears. Automatic recording of readings.

METROLOGIA APLICATĂ

No. 1, 1961, January-March

[illegible]

No. 2, April-June

[illegible]

No. 3, July-October

[illegible]

INDEX

MEASUREMENT TECHNIQUES

1961, Nos. 1-12

MEASUREMENT TECHNIQUES
1961, Nos. 1-12

A Translation of Izmeritel'naya Tekhnika

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

(Russian Original Dated January, 1961)

1961, No. 1, pp. 1-90 September, 1961

CONTENTS

CONTENTS (continued)

	PAGE	RUSS. PAGE

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

Russian Original Dated February, 1961

1961, No. 2, pp. 91-174 October, 1961

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR
Russian Original Dated March, 1961

1961, No. 3, pp. 175-258 November, 1961

CONTENTS

CONTENTS (continued)

	PAGE	RUSS. PAGE
MATERIAL RECEIVED BY THE EDITORIAL BOARD		
Checking the Quality of Instrument Production. P. M. Larionov	247	60
Using the Frequency of 100 kc Transmitted by Radio. N. F. Semenyuta	248	61
Protective Glass for an Eyepiece. A. P. Nikonorov	249	61
Checking the Quality of Recordings in Thermal Instruments. A. D. Snagovskii	249	62
Improvements in Testing Equipment. D. I. Mogilevskii	250	62
FROM FOREIGN JOURNALS	251	63
COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS		
New GOST (All-Union State Standard) "Mechanical Units"	254	64
I. New Specifications for Measures and Measuring Instruments Approved by the Committee	254	64
II. Measures and Measuring Instruments Approved by the Committee as the Result of State Tests and Passed for Use in the USSR	254	64

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

Russian Original Dated April, 1961

1961, No. 4, pp. 259-340 November, 1961

CONTENTS

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

(Russian Original Dated May, 1961)

1961, No. 5, pp. 341-426 December, 1961

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR
Russian Original Dated June, 1961

1961, No. 6, pp. 427-514 December, 1961

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

Russian Original Dated July, 1961

1961, No. 7, pp. 515-600 December, 1961

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

(Russian Original Dated August, 1961)

1961, No. 8, pp. 601-686 February, 1962

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

Russian Original Dated September, 1961

1961, No. 9, pp. 687-770 February, 1962

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

(Russian Original Dated October, 1961)

1961, No. 10, pp. 771-856 March, 1962

CONTENTS

CONTENTS (continued)

	PAGE	RUSS. PAGE
MATERIAL RECEIVED BY THE EDITORIAL BOARD		
Improving the Exchange of Experience Between the GKLs. I. I. Kogan	839	56
Utilizing Checking and Heavy Inspections for Instructional Purposes. N. M. Ershov	840	57
Greater Attention Should be Paid to Rationalizing Testing. D. M. Sizov	841	57
Supervision of Measurement Equipment in Metallurgical Production. K. N. Kizhaev	842	58
INFORMATION		
Problems of Radio-Measurement Technology at the Session Dedicated to the Radio Day	844	59
2nd International Conference of the IMEKO. V. O. Arutyunov and A. N. Gavrilov	845	60
Conference of the ISO and IEEC on Acoustics and Electrical Acoustics. I. G. Rusakov	848	62
FROM FOREIGN JOURNALS	850	63
IN THE COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS		
I. New Specifications for Measures and Measuring Instruments approved by the Committee	853	64
II. Operating Instructions Issued for Testing Measures and Measuring Instruments and approved by the Committee's Measuring Instruments Administration	853	64
III. Measures and Measuring Instruments approved by the Committee as the result of State Testing and passed for Use in the USSR	853	64

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

(Russian Original Dated November, 1961)

1961, No. 11, pp. 857-934 May, 1962

CONTENTS

CONTENTS (continued)

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR

Russian Original Dated December, 1961

1961, No. 12, pp. 935-1064 June, 1962

CONTENTS

CONTENTS (continued)

Soviet Journals Available in Cover-to-Cover Translation

ABBREVIATION	RUSSIAN TITLE		TITLE OF TRANSLATION	PUBLISHER	TRANSLATION BEGAN Vol.	Issue	Year
AÉ	Atomnaya énergiya		Soviet Journal of Atomic Energy	Consultants Bureau	1	1	1956
Akust. zh.	Akusticheskii zhurnal		Soviet Physics – Acoustics	American Institute of Physics	1	1	1955
	Antibiotiki		Antibiotics	Consultants Bureau	4	1	1959
Astr(on). zh(urn).	Astronomicheskii zhurnal		Soviet Astronomy—AJ	American Institute of Physics	34	1	1957
Avto(mat). svarka	Avtomaticheskaya svarka		Automatic Welding	British Welding Research Association (London)		1	1959
	Avtomatika i Telemekhanika		Automation and Remote Control	Instrument Society of America	27	1	1956
	Biofizika		Biophysics	National Institutes of Health*		1	1957
	Biokhimiya		Biochemistry	Consultants Bureau	21	1	1956
Byull. éksp(erim). biol. i med.	Byulleten' éksperimental'noi biologii i meditsiny		Bulletin of Experimental Biology and Medicine	Consultants Bureau	41	1	1959
DAN (SSSR) Dokl(ady) AN SSSR	Doklady Akademii Nauk SSSR		The translation of this journal is published in sections, as follows:				
		Life Sciences	Doklady Biochemistry Section	American Institute of Biological Sciences	106	1	1956
		Life Sciences	Doklady Biological Sciences Sections (Includes: Anatomy, biophysics, cytology, ecology, embryology, endocrinology, evolutionary morphology, genetics, histology, hydrobiology microbiology, morphology, parasitology, physiology, zoology sections)	American Institute of Biological Sciences	112	1	1957
		Life Sciences	Doklady Botanical Sciences Sections (Includes: Botany, phytopathology, plant anatomy, plant ecology, plant embryology, plant physiology, plant morphology sections)	American Institute of Biological Sciences	112	1	1957
		Chemical Sciences	Proceedings of the Academy of Sciences of the USSR, Section: Chemical Technology	Consultants Bureau	106	1	1956
		Chemical Sciences	Proceedings of the Academy of Sciences of the USSR, Section: Chemistry	Consultants Bureau	106	1	1956
		Chemical Sciences	Proceedings of the Academy of Sciences of the USSR, Section: Physical Chemistry	Consultants Bureau	112	1	1957
		Earth Sciences	Doklady Earth Sciences Sections (Includes: Geochemistry, geology, geophysics, hydrogeology, mineralogy, paleontology, petrography, permafrost sections)	American Geological Institute	124	1	1959
		Earth Sciences	Proceedings of the Academy of Sciences of the USSR, Section: Geochemistry	Consultants Bureau	106-123	1 6	1957-1958
		Earth Sciences	Proceedings of the Academy of Sciences of the USSR, Sections: Geology	Consultants Bureau	106-123	1 6	1957-1958
		Mathematics	Doklady Soviet Mathematics	The American Mathematics Society	131	1	1961
		Physics	Soviet Physics—Doklady (Includes: Aerodynamics, astronomy, crystallography, cybernetics and control theory, electrical engineering, energetics, fluid mechanics, heat engineering, hydraulics, mathematical physics, mechanics, physics, technical physics, theory of elasticity sections)	American Institute of Physics	106	1	1956
		Physics	Proceedings of the Academy of Sciences of the USSR, Applied Physics Sections (does not include mathematical physics or physics sections)	Consultants Bureau	106-117	1	1956-1957
Derevoobrabat. prom-st'.	Derevoobrabatyvayushchaya promyshlennost'		Wood Processing Industry	Timber Development Association (London)		9	1959
	Élecktrosvyaz		Telecommunications	Massachusetts Institute of Technology*		1	1957
Éntom(ol). oboz(renie)	Éntomologicheskoe obozrenie		Entomological Review	American Institute of Biological Sciences	38	1	1959
Farmakol. (i) toksikol(ogiya)	Farmakologiya i toksikologiya		Pharmacology and Toxicology	Consultants Bureau	20	1	1957
FMM	Fizika metallov i metallovedenie		Physics of Metals and Metallography	Acta Metallurgica*	5	1	1957
Fiziol. zhurn. SSSR (im. Sechenova)	Fiziologicheskii zhurnal im. I. M. Sechenova		Sechenov Physiological Journal USSR	National Institutes of Health*		1	1957
Fiziol(ogiya) rast.	Fiziologiya rastenii		Plant Physiology	American Institute of Biological Sciences	4	1	1957
	Geokhimiya		Geochemistry	The Geochemical Society		1	1958
FTT	Fizika tverdogo tela		Soviet Physics—Solid State	American Institute of Physics	1	1	1959
Izmerit. tekh(nika)	Izmeritel'naya tekhnika		Measurement Techniques	Instrument Society of America		1	1959
Izv. AN SSSR, O(td). Kh(im). N(auk)	Izvestiya Akademii Nauk SSSR: Otdelenie khimicheskikh nauk		Bulletin of the Academy of Sciences of the USSR: Division of Chemical Sciences	Consultants Bureau		1	1952

continued

Izv. AN SSSR, O(td). T(ekhn). N(auk): Met(all). i top.	(see Met. i top.)					
Izv. AN SSSR Ser. fiz(ich).	Izvestiya Akademii Nauk SSSR: Seriya fizicheskaya	Bulletin of the Academy of Sciences of the USSR: Physical Series	Columbia Technical Translations		1	1954
Izv. AN SSSR Ser. geofiz.	Izvestiya Akademii Nauk SSSR: Seriya geofizicheskaya	Bulletin (Izvestiya) of the Academy of Sciences USSR: Geophysics Series	American Geophysical Union		1	1954
Izv. AN SSSR Ser. geol.	Izvestiya Akademii Nauk SSSR: Seriya geologicheskaya	Izvestiya of the Academy of Sciences of the USSR: Geologic Series	American Geological Institute		1	1958
Kauch. i rez.	Kauchuk i rezina	Soviet Rubber Technology	Research Association of British Rubber Manufacturers	18	1	1959
	Kinetika i kataliz	Kinetics and Catalysis	Consultants Bureau	1	3	1960
	Koks i khimiya	Coke and Chemistry USSR	Coal Tar Research Association (Leeds, England)		1	1958
Kolloidn. zh(urn).	Kolloidnyi zhurnal	Colloid Journal	Consultants Bureau	14	1	1952
	Kristallografiya	Soviet Physics – Crystallography	American Institute of Physics	2	1	1957
Metalov. i term. obrabot. metal.	Metallovedenie i termicheskaya obrabotka metallov	Metal Science and Heat Treatment of Metals	Acta Metallurgica	6	1	1958
	Metallurg	Metallurgist	Acta Metallurgica		1	1957
Met. i top.	Metallurgiya i topliva	Russian Metallurgy and Fuels	Eagle Technical Publications		1	1960
Mikrobiol.	Mikrobiologiya	Microbiology	American Institute of Biological Sciences	26	1	1957
OS	Optika i spektroskopiya	Optics and Spectroscopy	American Institute of Physics		6	1959
	Pochvovedenie	Soviet Soil Science	American Institute of Biological Sciences		1	1958
	Priborostroenie	Instrument Construction	British Scientific Instrument Research Association		1	1959
Pribory i tekhn. éks(perimenta)	Pribory i tekhnika éksperimenta	Instruments and Experimental Techniques	Instrument Society of America		1	1957
Prikl. matem. i mekh.	Prikladnaya matematika i mekhanika	Applied Mathematics and Mechanics	American Society of Mechanical Engineers		1	1958
PTÉ	(see Pribory i tekhn. éks.)					
	Problemy Severa	Problems of the North	National Research Council of Canada			
Radiotekh.	Radiotekhnika	Radio Engineering	Massachusetts Institute of Technology*	12	1	1957
Radiotekh. i élektronika	Radiotekhnika i élektronika	Radio Engineering and Electronics	Massachusetts Institute of Technology*	2	1	1957
	Stanki i instrument	Machines and Tooling	Production Engineering Research Assoc.		1	1959
	Stal'	Stal (In English)	Iron and Steel Institute		1	1959
Stek. i keram.	Steklo i keramika	Glass and Ceramics	Consultants Bureau	13	1	1956
Svaroch. proiz-vo	Svarochnoe proizvodstvo	Welding Production	British Welding Research Association		4	1959
Teor. veroyat. i prim.	Teoriya veroyatnostei i ee primenenie	Theory of Probability and Its Applications	Society for Industrial and Applied Mathematics		1	1956
Tsvet. Metally	Tsvetnye metally	Nonferrous Metals	Primary Sources		1	1960
UFN	Uspekhi fizicheskikh Nauk	Soviet Physics – Uspekhi (partial translation)	American Institute of Physics	66	1	1958
UKh	Uspekhi khimii	Russian Chemical Reviews	The Chemical Society (London)		1	1960
UMN	Uspekhi matematicheskikh nauk	Russian Mathematical Surveys	London Mathematical Society	15	1	1960
Usp. fiz. nauk	(see UFN)					
Usp. khim(ii)	(see UKh)					
Usp. matem. nauk	(see UMN)					
Usp. sovr. biol.	Uspekhi sovremennoi biologii	Russian Review of Biology	Oliver and Boyd		48	1959
Vest. mashinostroeniya	Vestnik mashinostroeniya	Russian Engineering Journal	Production Engineering Research Assoc.		4	1959
Vop. gem. i per. krovi	Voprosy gematologii i perelivaniya krovi	Problems of Hematology and Blood Transfusion	National Institutes of Health*		1	1957
Vop. onk.	Voprosy onkologii	Problems of Oncology	National Institutes of Health*		1	1957
Vop. virusol.	Voprosy virusologii	Problems of Virology	National Institutes of Health*		1	1957
Zav(odsk). lab(oratoriya)	Zavodskaya laboratoriya	Industrial Laboratory	Instrument Society of America	25	1	1959
ZhAKh Zh. anal(it). khimii	Zhurnal analiticheskoi khimii	Journal of Analytical Chemistry USSR	Consultants Bureau	7	1	1952
ZhETF Zh. éksperim. i teor. fiz.	Zhurnal éksperimental'noi i theoreticheskoi fiziki	Soviet Physics—JETP	American Institute of Physics	28	1	1955
ZhFKh Zh. fiz. khimii	Zhurnal fizicheskoi khimii	Russian Journal of Physical Chemistry	The Chemical Society (London)		7	1959
ZhMÉI Zh(urn). mikrobiol. épidemiol. i immunobiol.	Zhurnal mikrobiologii, épidemiologii i immunobiologii	Journal of Microbiology, Epidemiology and Immunobiology	National Institutes of Health*		1	1957
ZhNKh Zh(urn). neorgan(ich). khim(ii)	Zhurnal neorganicheskoi khimii	The Russian Journal of Inorganic Chemistry	The Chemical Society (London)		1	1959
ZhOKh Zh(urn). obshch(ei) khimii	Zhurnal obshchei khimii	Journal of General Chemistry USSR	Consultants Bureau	19	1	1949
ZhPKh Zh(urn). prikl. khimii	Zhurnal prikladnoi khimii	Journal of Applied Chemistry USSR	Consultants Bureau	23	1	1950
ZhSKh Zh(urn). strukt. khimii	Zhurnal strukturnoi khimii	Journal of Structural Chemistry	Consultants Bureau	1	1	1960
ZhTF Zh(urn). tekhn. fiz.	Zhurnal teknicheskoi fiziki	Soviet Physics—Technical Physics	American Institute of Physics	26	1	1956
Zh(urn). vyssh. nervn. deyat. (im. Pavlova)	Zhurnal vysshei nervnoi deyatel'nosti (im. I. P. Pavlova)	Pavlov Journal of Higher Nervous Activity	National Institutes of Health*		1	1958

*Sponsoring organization. Translation through 1960 issues is a publication of Pergamon Press.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

AN SSSR	*Academy of Sciences, USSR*
FIAN	*Physics Institute, Academy of Sciences USSR*
GITI	*State Scientific and Technical Press*
GITTL	*State Press for Technical and Theoretical Literature*
GOI	*State Optical Institute*
GONTI	*State United Scientific and Technical Press*
Gosénergoizdat	*State Power Press*
Gosfizkhimizdat	*State Physical Chemistry Press*
Goskhimizdat	*State Chemistry Press*
GOST	*All-Union State Standard*
Gostekhizdat	*State Technical Press*
GTTI	*State Technical and Theoretical Press*
IAT	*Institute of Automation and Remote Control*
IF KhI	*Institute of Physical Chemistry Research*
IFP	*Institute of Physical Problems*
IL	*Foreign Literature Press*
IPF	*Institute of Applied Physics*
IPM	*Institute of Applied Mathematics*
IREA	*Institute of Chemical Reagents*
ISN (Izd. Sov. Nauk)	*Soviet Science Press*
IYap	*Institute of Nuclear Studies*
Izd	*Press (publishing house)*
LÉTI	*Leningrad Electrotechnical Institute*
LFTI	*Leningrad Institute of Physics and Technology*
LIM	*Leningrad Institute of Metals*
LITMiO	*Leningrad Institute of Precision Instruments and Optics*
Mashgiz	*State Scientific-Technical Press for Machine Construction Literature*
MGU	*Moscow State University*
Metallurgizdat	*Metallurgy Press*
MOPI	*Moscow Regional Pedagogical Institute*
NIAFIZ	*Scientific Research Association for Physics*
NIFI	*Scientific Research Institute of Physics*
NIIMM	*Scientific Research Institute of Mathematics and Mechanics*
NIKFI	*Scientific Institute of Motion Picture Photography*
NKTM	*People's Commissariat of the Heavy Machinery Industry*
Obrongiz	*State Press of the Defense Industry*
OIYaI	*Joint Institute of Nuclear Studies*
ONTI	*United Scientific and Technical Press*
OTI	*Division of Technical Information*
OTN	*Division of Technical Science*
RIAN	*Radium Institute, Academy of Sciences of the USSR*
SPB	*All-Union Special Planning Office*
Stroiizdat	*Construction Press*
URALFTI	*Ural Institute of Physics and Technology*
TsNIITMASh	*Central Scientific Research Institute of Technology and Machinery*
VNIIM	*All-Union Scientific Research Institute of Metrology*

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

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